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Engineering Aspects

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By E. A. Harrell[1] and J. G. Griffin[2]

ABSTRACT

This publication presents the engineering developments and equipment specifications necessary for constructing a workable, economically feasible rearing system capable of supplying a minimum of 10 million usable boll weevils per 7-d week, using an 8-h work shift per day. This system should also be of value in developing different levels of technology for the mass rearing of other insects. Index terms: *Anthonomus grandis* Boheman, insect-rearing equipment, large-scale insect rearing.

INTRODUCTION

Recent research contributions by entomologists, pathologists, and engineers have culminated in the development of a system suitable for mass rearing of the boll weevil, *Anthonomus grandis* Boheman. The engineering research, which was conducted in the Boll Weevil Research Laboratory at Mississippi State, Miss., involved all phases of boll weevil rearing, while research conducted in the Southern Grain Insects Research Laboratory at Tifton, Ga., involved equipment and techniques for larval production only.

Engineering developments are discussed in this publication, and specifications necessary for construction of a rearing system capable of supplying a minimum of 10 million usable boll weevils (above colony requirements) per 7-d week, using an 8-h work shift per day, are presented. Research to develop the system was aimed at the most troublesome or costly areas, i.e., reduction of labor through mechanization and improvement in techniques limiting production. Thus, all areas of the system, which are discussed in sequence, have not been given equal or adequate engineering attention. The major areas of a typical boll weevil rearing facility are shown in figure 1.

GENERAL REQUIREMENTS

Sanitation in most of the rearing areas is an important factor in the mass rearing of boll weevils. Thus, it is necessary that adequate cleaning and disinfecting measures be followed, not only in removing microbes from the air but also in keeping the floors, walls, equipment, and work surfaces free of these organisms. This will require surfaces that are nonporous, free of cracks or crevices, smooth, and capable of withstanding washing, mopping, and spraying with disinfecting or sanitizing agents. Materials and construction methods for floors, walls, ceilings, tables, and other equipment used in the rearing operation must be carefully selected to meet these requirements. A floor covering composed of a concrete base

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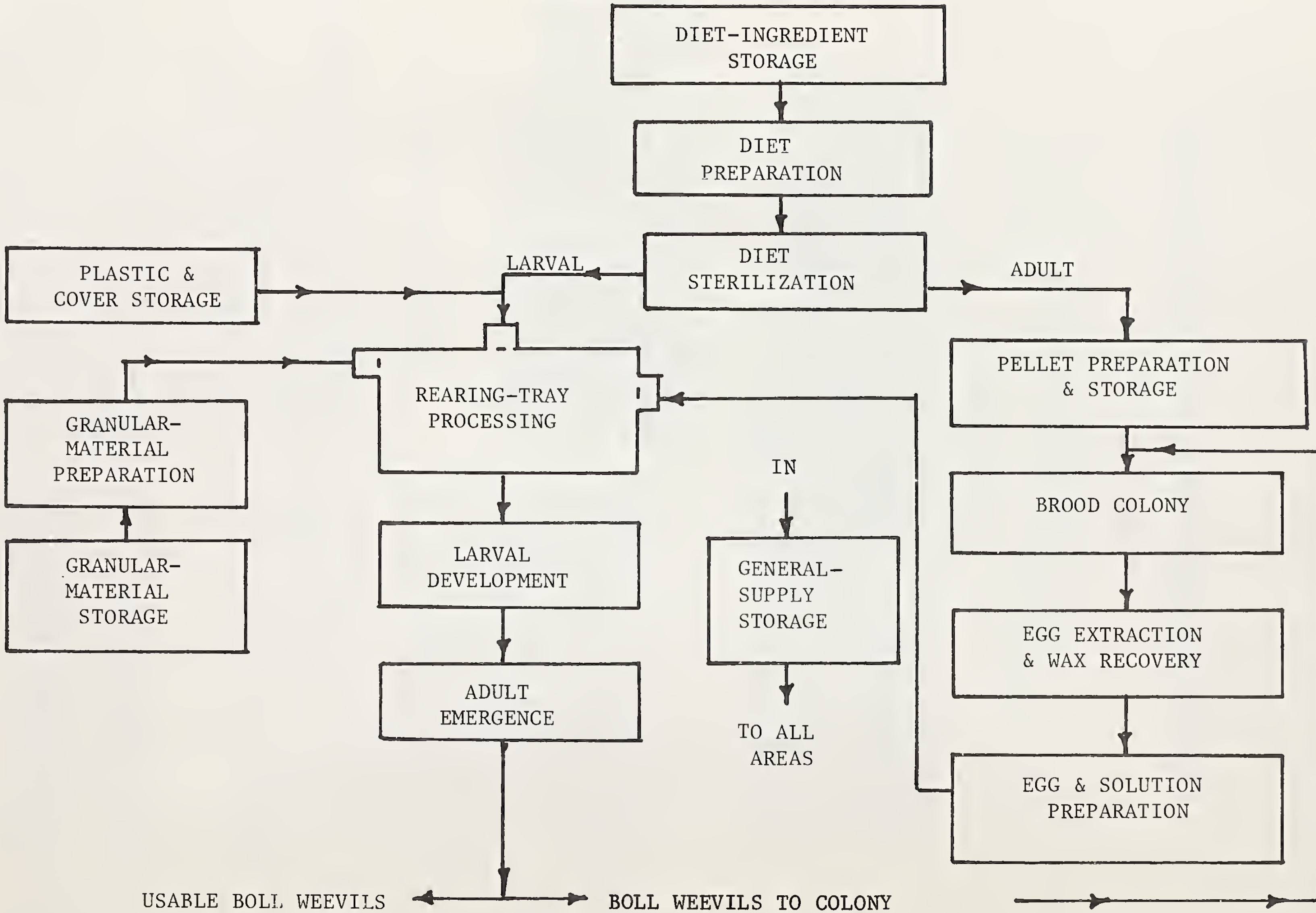


FIGURE 1.—Block diagram of major areas in a boll weevil rearing facility.

and a thin ($\frac{1}{8}$- to $\frac{3}{16}$-in-thick) troweled-on mortar base with a liquid synthetic top covering has not performed satisfactorily in some of the rooms in the Boll Weevil Research Laboratory at Mississippi State, Miss. The material cracks, and, with water on the floor, the entire layer (topping and base) peels from the concrete. This floor covering is also easy to dent when an object is dropped on it, especially if the object has sharp points or corners. These dents make the floor difficult to keep clean.

To better control outside air entering the building, window units should have stationary glass panels that are insulated to conserve energy and help maintain a more uniform inside temperature.

All outside air entering any of the air-handling systems should be filtered with a high-efficiency, particulate-air (HEPA) filter rated at least 95% efficient by the standard dioctylphthalate (DOP) test. Space air heating and cooling can be provided with hot- and cold-water coils in an air-handling system. The water is heated with steam from a boiler and cooled with a mechanical refrigeration liquid chiller. The control units and conditioning system should maintain the temperature at the sensor location within $\pm 2°$ F of the set point.

Interior walls covered with gypsum board and painted with epoxy paint have shown rapid deterioration in the Robert T. Gast Rearing Laboratory at Mississippi State. However, masonry units provide a surface that is smooth enough to be easily cleaned and one that can withstand cleaning and spraying solutions as well as physical bumps. Although the original cost of gypsum-board wall construction might be less than that of masonry walls, the long-range maintenance and replacement costs would probably favor the masonry construction. However, ceiling surfaces do not get as much abuse as walls, and gypsum board installed in ceilings has performed satisfactorily except when liquid leaks have occurred above ceiling level.

All doors and frames should be made of heavy-duty metal coated with a baked-on primer and painted with three coats of rust-resistant metal enamel. All outside doors should be fitted with heavy-duty door closers.

Utility entrance to a room through the floor should be avoided as much as possible except in wall cavities. When utilities enter through an open floor area, precautions must be taken to ascertain that a good smooth bond, without cracks or crevices, exists between the floor and the utility carrier.

As indicated above, rooms in some of the areas of the rearing building require special environments, whereas other rooms require only a normal human-comfort environment. Because of the environmental and sanitation requirements, most areas, and in some cases a room within an area, require an individual air-conditioning and control system. Airflow between some rooms must be eliminated to maintain necessary levels of sanitation.

Restrooms should be designed and located to reduce transfer of organisms by personnel from one area to another. Also, all areas should have access to a shower, but clean areas, such as the rearing-tray processing area, should be provided with a separate shower and a room in which to change from street to laboratory clothes.

A high-pressure (125-lb/in^2) steam boiler is required to furnish steam for the diet sterilizers, and the same boiler may be used to furnish lower pressure steam for heating water, steam kettles, and humidifiers or for other purposes in the rearing operation. A refrigeration liquid-chiller unit is required for cooling. This chiller may also be used as a source of cold water for making diet pellets, or a separate chiller may be used. Because of the loss in production and other detrimental effects that occur if air cooling is lost during outside high-temperature periods, a backup unit for the liquid chiller is necessary. We recommend that a backup boiler also be available. The major equipment components should not be operated more than 7 h of any 8-h period. The remaining hour should be reserved for maintenance, repair, cleaning, and sanitizing.

There are many components in the rearing system in which a slight change could alter the system tremendously. For instance, larval-tray processing could easily be doubled, but all the required support systems have not been obtained and tested. When a change in the system is considered, all components of the system must be analyzed for possible effects. Doubling the size of the system does not assure doubling the output. Those responsible for the design and building of a rearing facility should consult all disciplines concerned for an update on current technology.

Labor is a very important part of the rearing system and can possibly be the difference between success and failure of the facility. The facility should be staffed with knowledgeable, skillful

personnel who understand and properly execute the required procedures.

DIET-INGREDIENT STORAGE AREA

The diet-ingredient-storage and diet-preparation areas should be located in a separate building from the main rearing facility. The building should be located at least 200 ft downwind (distance and direction determined by prevailing winds) from the rearing facility to reduce the transfer of dust particles and micro-organisms into the rearing area. Depending upon the arrangement of the entire rearing facility, the constraints of locating the diet-ingredient storage facility with regard to the main rearing facility, and the allowable particulates that can be exhausted into the surroundings, it may be necessary to filter the air exhausted from the diet-preparation area. Also, separation from the rearing facility discourages personnel from moving between areas without following proper sanitation procedures. The building should be designed to expedite the movement of materials into and out of it, prevent infestation by insects or rodents, and allow easy cleaning. If the diet-ingredient-storage and diet-preparation areas are located inside the rearing facility, they must be isolated to prevent direct passage into any other rearing areas.

Separate larval and adult diets are used in the production of boll weevils. The major ingredients are similar for both diets (table 1). For full production, a 6-week minimum supply (about 26 tons) of diet ingredients should be on hand or available locally for pickup as needed. Most of the ingredients can be stored in a dry, cool (60° to 75° F) area for short periods. Those requiring cold, dry storage may be placed in a room about 10 by 12 ft. It should be operated at about 40° F. In areas where mold is a problem, the humidity should be reduced to 40%. It might be desirable to also have a refrigerator with a capacity of about 17 ft^3. Windows are optional but if included should not exceed 5% of the floor area.

SPECIFICATIONS

A. Cool, dry storage room
   1. Size, 1,600 ft^2 (minimum)
   2. Wall height, 9 ft (minimum)
   3. Floor, concrete
   4. Ceiling lights, wall-switch controlled
   5. Duplex receptacles, 120-V, dustproof, placed along wall maximum 12 ft apart, only two per circuit
   6. Outside door, 8 by 8 ft (minimum), constructed and covered to prevent rain blow-in and rodent entrance
   7. Interior doors, 4 by 7 ft (minimum), between storage and preparation areas, with some glass area

B. Cold, dry storage room
   1. Temperature and humidity, 40°±3° F; 40%±2% RH
   2. Size, 10 by 12 by 8 ft, inside dimensions
   3. Inside light with outside switch control
   4. Indicating thermometer on outside
   5. Refrigeration door, heavy-duty
   6. Dehumidifier (if needed), Cargoaire Honeycomb model HC-150 or equivalent
      (a) Air capacity, 50 to 150 ft^3/min; typical reactivation capacity, 45 ft^3/min
      (b) Heat requirements, 7,500 Btu/h

C. Fork lift (for use inside and outside)
   1. Engine, gasoline-driven
   2. Capacity, 4,000 lb
   3. Lift height, 6-ft minimum, 10-ft maximum
   4. Tires, large pneumatic, on drive wheels about 7:00-12 and on steering wheels about 6:90-6; industrial heavy-duty, equal to at least six-ply

DIET-PREPARATION AREA

This area may consist of one-, two-, or three-room units located adjacent to or easily accessible to the diet-ingredient storage area. In a one-room

Table 1. — Major diet ingredients and quantity used for production of 10 million usable boll weevils per week

Diet ingredient	Pounds per day	Pounds per 6 weeks
Cottonseed meal (sifted)	645	27,090
Cottonseed meats	148	6,216
Promine D	152	6,384
Agar	107	4,494
Sugar	96	4,032
Corncob grits	48	2,016
Other	54	2,268
Total	1,250	52,500

unit, all operations are necessarily done in a single room. In a two-room unit, the weighing and proportioning are done in one room and the other operations in a separate room. In a three-room unit, the grinding and sifting are done in room 1, weighing or proportioning in room 2, and blending and mixing in room 3. The rooms and equipment should be arranged to allow for removal of ingredients from storage and for preparation of them for sterilization with a minimum of backtracking.

The valves in the sterilizer piston pump do not work properly with hard, solid particles above a certain size passing through them. Passing the materials through a 30- to 32-mesh screen made from 0.015-in-diameter wire has provided satisfactory operation of the valves. The major ingredients requiring preconditioning are cottonseed meal, which requires sifting, and cottonseed meats, which require grinding and sifting before use in the diet. Some of the other ingredients might require sifting to break lumps or to fluff after storage. It is desirable to sift the complete diet after if has been blended to remove any particles that would not pass through the 30-mesh screen. The diet-preparation crew should maintain at least a 3-d lead of prepared diet. Grinding, sifting, and blending the diet ingredients create dust; therefore, these rooms should be provided with air-exhaust and dust-collecting systems to keep the dust concentration to an acceptable level.

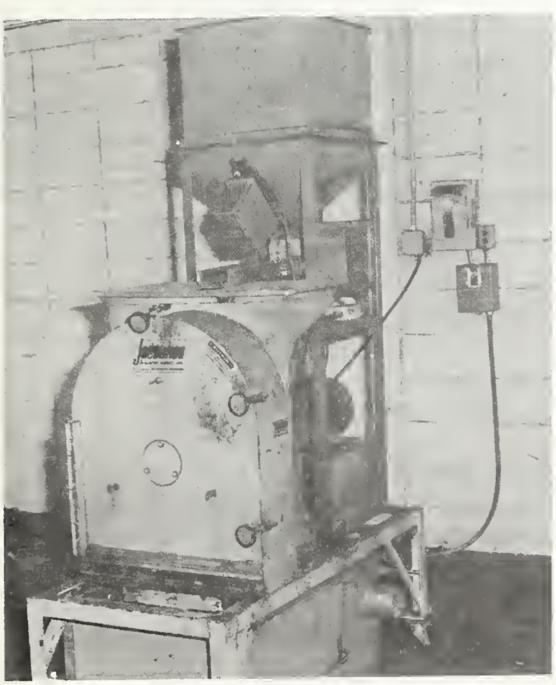


FIGURE 2.—Hammer mill with automatic feeder for grinding boll weevil diet ingredients.

Other diet-preparation alternatives should be investigated thoroughly before building a production facility. Several commercial companies have equipment and engineering services available to design and build a completely automated diet-preparation system. Also, there are companies that can supply prepared diets to specifications on contract as needed. A prepared diet delivered to a rearing facility as needed might reduce probable proportioning and mixing errors and some of the contamination problems in rearing insects.

SPECIFICATIONS

A. Diet-preparation area for one-, two-, and three-room units
   1. Floor area
      (a) One-room unit, 650 ft^2
      (b) Two-room unit
         (1) Room 1, 500 ft^2
         (2) Room 2, 150 ft^2
      (c) Three-room unit
         (1) Room 1, 360 ft^2
         (2) Room 2, 150 ft^2
         (3) Room 3, 160 ft^2
   2. Ceiling height, 9-ft minimum for all rooms
   3. Air-exhaust and dust-collection systems for each room
   4. Floor, concrete, with drain
   5. Walls, masonry, waterproofed outside and painted on inside
   6. Doors, 4 by 7 ft (minimum)
   7. Ceiling lights, explosion-proof, wall-switch controlled
   8. Duplex receptacles, 120-V, not more than 10 ft apart on walls, no more than two per 20-A circuit
   9. Electrical circuitry for each item of equipment sized to suit
   10. Window area not more than 10% of floor area

B. Equipment
   1. Pulverizing hammer mill, Jacobson model 160-D "full circle" or C.S. Bell Co. model 20 or equivalent (fig. 2), with the following components:
      (a) Screens, $^3/_{128}$-, $^1/_{16}$-, and $^1/_8$-in openings; larger opening screens require more than one grinding
      (b) Hammers, hard-faced

FIGURE 3.—Automatic feeder with sifter-shaker for screening boll weevil diet ingredients.

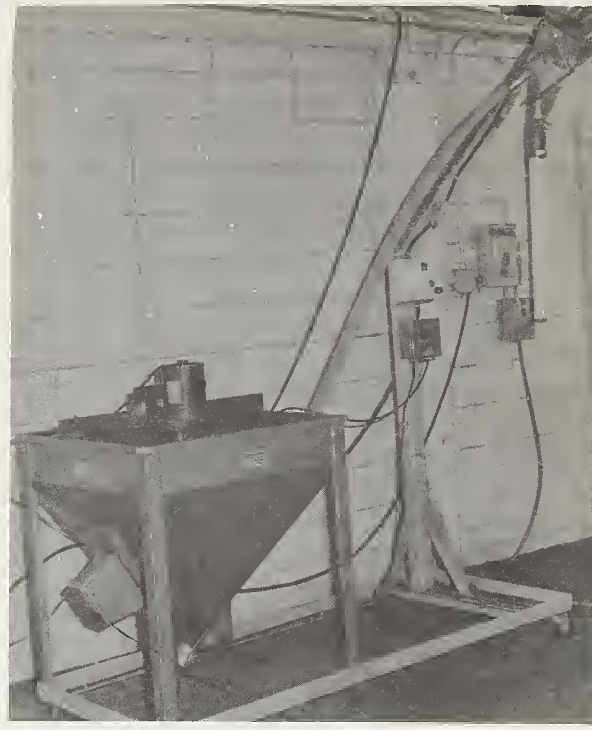


FIGURE 4.—Elevator for lifting and metering diet materials to hopper of hammer-mill feeder.

(c) Hopper with slide feed gate
(d) Cover, hinged or removable for quick screen change or cleaning
(e) Magnet, mounted on feed inlet hopper
(f) Motor, 5-hp, totally enclosed, 3-phase, 60-Hz, 208-V
(g) Blower with direct-drive coupling, feed-regulating gate, air-intake disk, and dust collector
(h) Magnetic starting switch with off-on pushbutton controls

2. Sifter-separator-scalper, Eriez Syncro-Matic screen separator or equivalent, capable of handling ground, dry materials such as cottonseed meal and similar products
(a) Screened deck, straight-frame, 36 in diameter (minimum), with 30-mesh stainless-steel screening cloth or equivalent
(b) Deck, antibinding, with cylinders or balls to keep screen cloth from choking up with material being screened
(c) Adjustments for vertical and horizontal movements of screened deck to provide for proper screening and feed-off; weights furnished
(d) Construction, carbon-steel, with baked-on enamel finish
(e) Motor (to be furnished), 2½-hp (minimum), explosion-proof frame, 3-phase, 60-Hz, 208-V

3. Automatic volumetric feeder unit, Eriez Magnetics or equivalent, automatically feeds material into sifter (fig. 3)
(a) Vibratory feeder, 6 in wide (minimum) and 28 in long; flat trough made of 16-gage mild steel
(b) Capacity, delivers 3 tons/h (minimum)
(c) Hopper, 3 ft^3 (minimum), mild-steel construction, with attached bin vibrator
(d) Motors, variable-speed, one for bin vibrator and one for feeder, both mounted in dustproof enclosures; single-phase, 60-Hz, 120-V
(e) Hopper and trough painted with metal enamel

4. Elevator, Aim Flex-Feeder model 50 or equivalent, for lifting and metering ma-

terials to hopper of hammer mill (fig. 4)
   (a) Flexible metal auger and feed tube, 10-ft minimum length for both
   (b) Hopper, 8 ft^3 (minimum)
   (c) Cleanout cap on bin end of tube
   (d) Motor, explosion-proof, with reversing starter
   (e) Agitator and bin vibrator added to hopper to prevent material from bridging
5. Scales, many suitable scales available, any of units described below can be selected to fill requirements of facility and personnel
   (a) Dual-range, top-loading Sartorius Electronics Balance model 3716MP or equivalent; weighing ranges, 0 to 300 g and 0 to 3,000 g with precision of ±0.005 g; single-phase, 60-Hz, 110-V
   (b) Mettler model P3N or equivalent, range in capacity of 0 to 3,000 g with at least 1-kg tare capacity; smallest division on scale, 1 g or less; single-phase, 60-Hz, 120-V
   (c) Mettler model E20N, range of 0 to 20 kg with variation in taring range of 5 kg with scale division of at least 10 g (maximum) but can be estimated to 2 g; single-phase, 60-Hz, 120-V
   (d) Digital Fairbanks H-70-4000-1, series 7, with 100-lb capacity read in 0.05-lb increments; display time in seconds, 0.5 nominal; display type, 0.625-in, 7-segment; digital tare, to full capacity; press button zero range, to full capacity; single-phase, 60-Hz, 110-V, 15-W; operating temperature, 0° to 50° C; RH, 0% to 100%
6. Tables, heavy-duty, for top-loading scales, 24- by 48-in top (minimum)
7. Sink, single-compartment, stainless-steel, 24 by 18 by 14 in, with 18- by 24-in sideboard made of 14-gage metal
8. Vitamin-mix blender, Patterson-Kelley model 1B-8S or equivalent, for blending several different vitamins and sugar together into vitamin mix
   (a) Twin-shell type with contact material made of stainless steel
   (b) Working capacity, 8 qt
   (c) Removable intensifier bar
   (d) Motors for bar and main shell to have separate switches

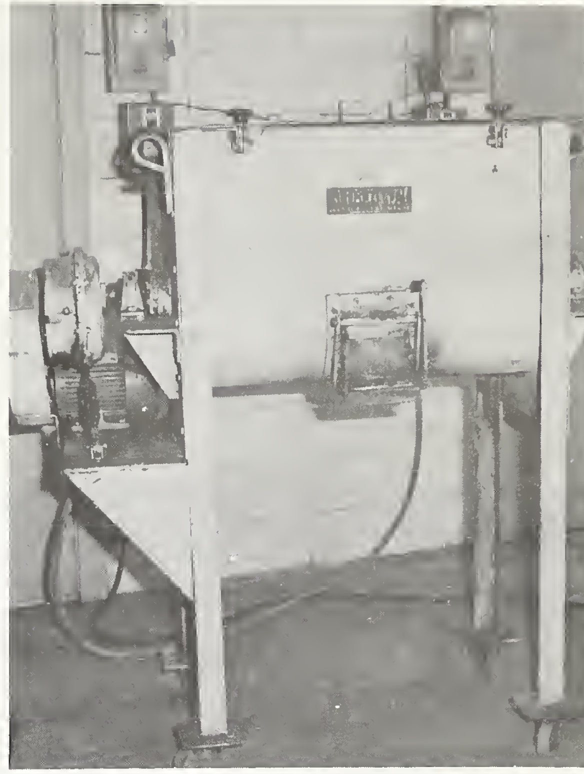


FIGURE 5.—Heavy-duty mixer for mixing insect diets.

   (e) Motor, explosion-proof, single-phase, 60-Hz, 120-V
   (f) Base and support arms, cast aluminum or enamel-painted steel
9. Bag holder
   (a) Universal bag holder with malleable-iron jaws
   (b) Bag height and width adjustable
   (c) Metal base to support bottom of bag
10. Mixer, Kelley-Duplex model 193 or equivalent (fig. 5)
   (a) Mixer-blender, heavy-duty, horizontal, paddle-type, for dry materials; working capacity, 6 ft^3, total capacity, 9 ft^3
   (b) Gear-reducer driver, heavy-duty
   (c) Metal thickness, 3/16-in end plates; 10-gage mild-steel body with inspection window
   (d) Cover, gasketed, dusttight, quick-removal
   (e) Gate discharge, slide-swing, dusttight
   (f) Minimum 32-in clearance from floor to discharge outlet

(g) Motor, 3-hp (minimum), 1,800-r/min, 3-phase, 60-Hz, 208-V, totally enclosed, fan-cooled; complete with motor mount, motor sheave, drive sheave, V-belts, and starter

DIET-STERILIZATION AREA

This area should not have a direct passageway to other areas of the rearing facility, except through hallways or outside walkways. It should be so located as to make it both accessible and convenient to bring the dry-ingredient mixture into the diet-sterilization room and to transfer the sterilized diet to the rearing-tray-processing and pellet-making areas. The sterilization room must be large enough for three sterilizer units, each with three 30-gal tanks (kettles), a worktable, a pair of scales, three 30-gal water-measuring tanks (if used), a double-compartment sink with double drainboards, and six diet-holding containers.

Three sterilizers (Griffin and Lindig 1974b, Harrell et al., 1977) are required. The third sterilizer produces diet for pellet making and serves as a backup unit. The pellet-making equipment requires a sterilizer that is capable of creating high pumping pressures (160 to 175 lb/in^2) or a separate high-pressure pump to push the diet through pelleting equipment. The larval diet may be sterilized with either coiled-tube or scrape-surface sterilizers; both have advantages and disadvantages. The major disadvantage of the coiled-tube, high-pressure sterilizer is an operating pressure of between 2,000 and 3,000 lb/in^2 for boll weevil diets, and ingredients must be ground fine enough to pass through a 30-mesh screen for proper operation. However, little diet is wasted on startup and shutdown. The major advantages of the scrape-surface, low-pressure sterilizers are lower operating pressure (30 to 40 lb/in^2) for boll weevil diets, and larger particles in the diet are more easily handled by the pumps. However, these sterilizers require from 2½ to 5 gal of diet in the startup and shutdown procedures. The vertical, scrape-surface sterilizer requires less floor space. The same types, makes, and models of sterilizers should be used for all sterilizing operations; this makes it easier to interchange parts and also reduces spare-parts inventories. The sterilizers must raise the temperature of the diet mixture to about 300° F and then cool it to a usable temperature (110° F) in a 1½- to 2-min period.

The mixed or blended diet ingredients may be moved into the sterilizing area in bulk or batches. With the bulk method, the diet is batched as needed. Each batch is thoroughly mixed with water in one of the 30-gal tanks on the sterilizer and then pumped through the sterilizer as needed. The water for each batch of diet is premeasured in a separate 30-gal measuring container before it enters a sterilizer tank or is measured in one of the 30-gal tanks on the sterilizer before addition of the diet mixture. One batch of diet from one of the 30-gal tanks is sterilized while another batch is mixed with water in another tank. The alternate changing of tanks to mix and sterilize continues throughout the run.

Good temperature-controller and recording systems are essential to assure that the diet reaches the sterilizing temperature and leaves the sterilizer at the proper working temperature. Two controllers are required for each sterilizer — one for heating and one for cooling. It is also desirable to have an extra cooling temperature controller near the diet dispenser.

SPECIFICATIONS

A. Sterilization room
   1. Size, about 20 by 30 ft, with concrete floor covered with broken quarry tile; floor drains, including P-trap; masonry walls painted with epoxy enamel; gypsum-board ceiling, 9 ft high (minimum), painted with epoxy enamel
   2. Recessed ceiling lights, wall-switch controlled
   3. Duplex receptacles, waterproof, 120-V, wall-mounted, not more than 10 ft apart, no more than two receptacles per 20-A circuit
   4. Ceiling receptacles (three each), drop cord located over each sterilizer; 20-A, 3-phase, 60-Hz, 208- or 230-V
   5. Width of door for diet and equipment entrance, 4 ft (minimum)
   6. Restroom, includes shower stall, dressing area (8 by 10 ft), lavatory, and water closet located in a stall
   7. Utilities required, other than electrical
      (a) Hot and cold water at sink
      (b) Cold water at each sterilizer location
      (c) Steam, 80-lb/in^2 minimum at each sterilizer location
      (d) Steam-condensate return drain at each sterilizer location

(e) Air supply, 40 lb/in^2 at sterilizer location if air-operated mixer units are used; if electric mixers are used install drop-cord receptacle, single-phase, 60-Hz, 120-V

(f) Room air conditioned for human comfort

(g) Regular utilities in restroom

(h) Cold-water supply for water cooling

B. Equipment

1. Sterilizer, Cherry-Burrell Corp. No-Bac-Unitherm IV or equivalent, high-pressure, coiled-tube type (fig. 6)

(a) Design, self-contained system for processing fluid products aseptically with components mounted on a common base; prepiped and wired so that, upon connecting electrical power, steam, and water, system is ready to operate

(b) Capacity, 22.5 to 45 gal/h of liquid product having maximum viscosity of 250 Sus at the supply or pumping temperature of product

(c) Product mixing tanks (two each), 30-gal, stainless-steel, with mixers

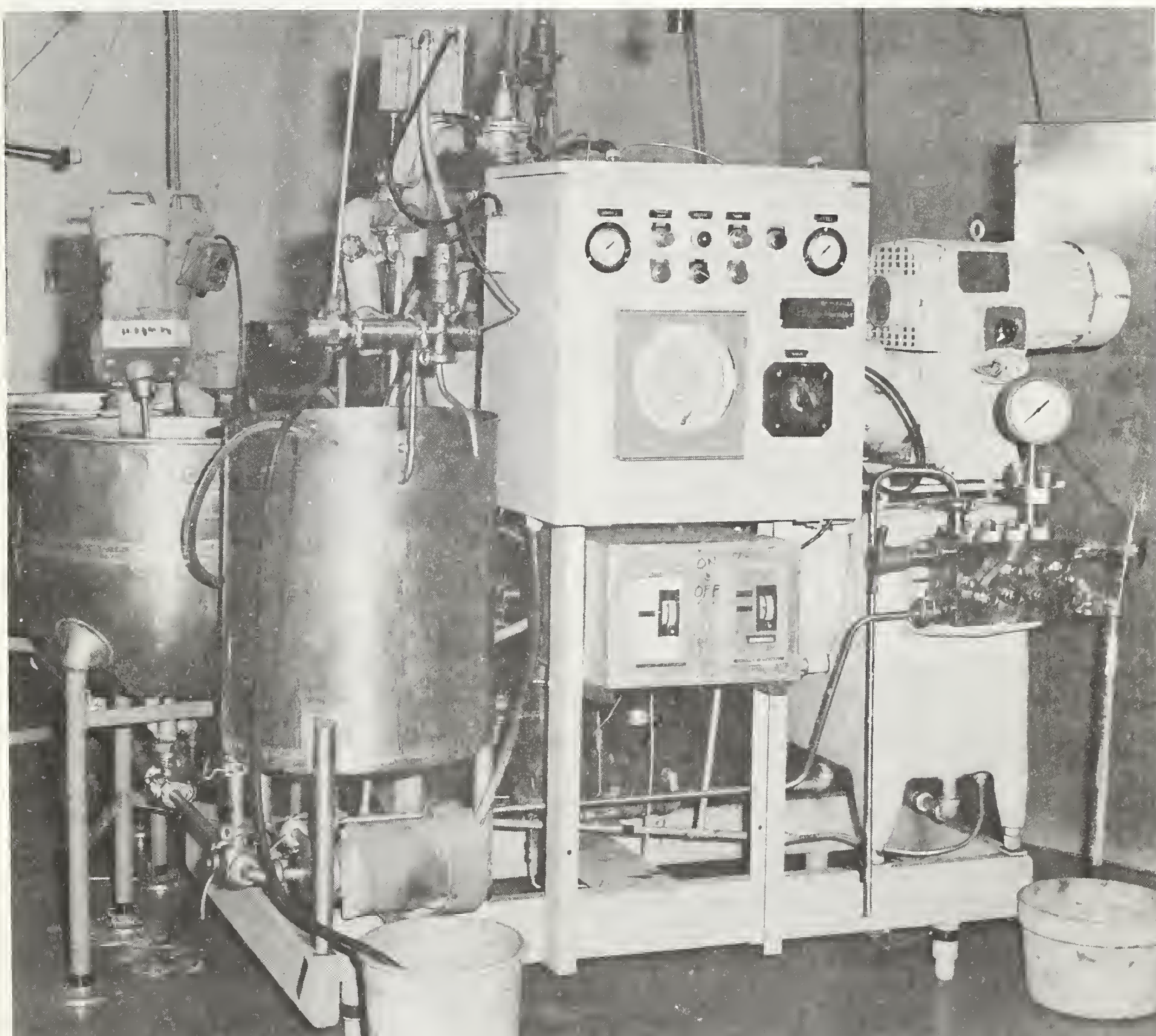


FIGURE 6.—High-pressure, coiled-tube sterilizer with temperature controllers for sterilizing insect diets.

(d) Cleanup tank, 30-gal, stainless-steel, for holding the washing and sanitizing solutions

(e) High-pressure pump, Stellar model 200 or equivalent, complete with magnetic starters and switches; 5-hp, 3-phase, 60-Hz, 230-V, with variable-speed drive and pressure-relief valves; maximum pressure, 3,000 lb/in^2

(f) Supply pump, model OH Flex Flo or equivalent, complete with magnetic starters and switches; ½-hp, 3,450-r/min, 3-phase, 60-Hz, 208- or 230-V

(g) Heat exchangers, consist of three steam-heating sections, one holder section, two steam gages (0 to 60 lb/in^2 and 0 to 100 lb/in^2), two cooler sections, one precooler, one final cooler, two steam traps, two steam regulators (0 to 40 lb/in^2 and 0 to 100 lb/in^2), and four product inline thermocouples (type T, copper constantan); heat exchangers set up with two preheat exchangers in series that use 30 lb/in^2 or less of steam pressure with appropriate pressure regulator and bucket trap to raise temperature of product flowing at rate of 45 gal/h from about 70° to 220° F; one final heat exchanger using 80 lb/in^2 of steam pressure with pressure regulator and bucket trap capable of raising temperature of product flowing at maximum rate of 45 gal/h (specific heat, 1.1) from 220° to 300° F; one holding coil with capacity to hold maximum flow rate for minimum of 30 s; one precooler; and one final cooling heat exchanger in series capable of lowering temperature of product flowing at maximum rate from 280° to 100° F using cooling water at 70° F in each of cooling heat exchangers

(h) Valve manifold, includes 1½-in back-pressure valve, No-Bac 60 RTMQ, and manual 1-in diversion valve, No-Bac 90 CTPQ

(i) Control panel, contains one painted carbon-steel enclosure, one electronic temperature-indicator recorder and selector switch, one four-station rotor selector switch for thermocouples, four start-stop switches for pumps and agitators, one starter for high-pressure pump motor, and one starter for model OH pump

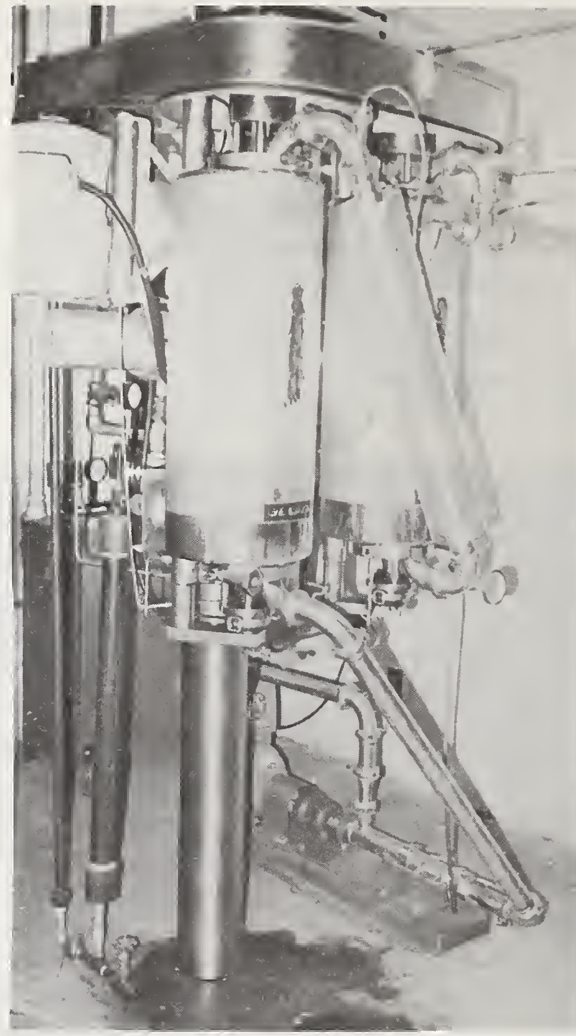


FIGURE 7.—Vertical, low-pressure, scrape-surface sterilizer for sterilizing insect diets.

(j) Product tubes, heat exchanger, shells, and end flanges made of stainless steel

2. Sterilizer, Contherm or Votator, low-pressure, scrape-surface type (fig. 7), performs same functions as high-pressure sterilizer and consists of the following components:

(a) Heat exchangers, one for heating with steam and one for cooling with water; all product contact surfaces made of 304 stainless steel except

heat-exchanger surface of pure nickel substrate with honed, hard-chrome product contact surface and scraper blades of hardened, ground stainless steel; head gasket made of Buna N standard gasket material

(b) Motor-drive packages (two each), including 5-hp, 1,200-r/min, 3-phase, 60-Hz, 208- or 230-V, totally enclosed, fan-cooled motor, with motor shield, drive shield, supplying couplings, bearings, V-belt, belt guard, motor mounting, and motor takeup; also one set of 2-in interconnecting pipes, one steam valve with single-indicating control, and one steam trap

(c) Hydraulic rotor lifting system for raising and lowering rotor assemblies, includes ¾-hp, 1,725-r/min, 3-phase, 60-Hz, 208- or 230-V motor with integral pump and 2-gal oil reservoir, four-way hydraulic control valve, and stainless-steel tubing with compression fittings; also 3-in (o.d.) two-bladed rotor, standard carbon seals, 2-in product portside connections, and standard vertical stainless-steel column mounting for the two Contherm units

(d) Control panel with pushbutton stop-start stations and magnetic starters

(e) Pump, Mono F4, with ¾-hp, variable-speed-drive, 3-phase, 60-Hz, 208-V motor

(f) Product mixing tanks (two each), 30-gal, stainless-steel, with mixers

(g) Cleanup tank, 30-gal, stainless-steel, for holding the washing and sanitizing solutions

3. Product mixing tanks, two for each sterilizer

   (a) Construction, type 304 stainless steel, bottoms rounded or sloped to opening in bottom, threaded for 1-in national pipe thread

   (b) Rolled sanitary rim

   (c) Mounted on minimum of three round, painted metal legs

   (d) Three-way plug valve (rubber plug), stainless-steel, sanitary, with 1-in triclamp fitting connections (two each)

   (e) Adapter, stainless-steel, 1-in national pipe thread to 1-in triclamp

   (f) Triclamps, gaskets, and 1-in stainless-steel pipe with triclamp fittings for connecting tank to systems and drains

4. Sterilizer temperature controllers, Barber Colman solid state 500 series or equivalent, automatically regulate flow of steam or cooling water to maintain temperature of diet product to preset values; two required per sterilizer, one for heating and one for cooling

   (a) Solid-state, indicating, with adjustable low-level alarm; proportioning band, zero to 5% up to 50% of span; automatic reset; range, 0° to 400° F; operate on type T thermocouples; single-phase, 60-Hz, 120-V

   (b) Modulating steam valve, Barber Colman medium-torque motorized valve or equivalent; electrically actuated, single-set, packed globe body with stainless-steel trim and characterized V-pointed inner valve threaded in stainless steel; seat renewable; static pressure ring of 150 lb/in^2; full open to full close within 10 to 12 s; single-phase, 60-Hz, 120-V; operated by above controllers with all linkage included; six units with ½-in national-pipe-thread ends or valves that will allow 6 to 8 gal/min of waterflow at pressures of 45 to 50 lb/in^2

5. Scales, 100-lb range (See "Diet-Preparation Area" section for complete specifications)

6. Worktable

   (a) Size, 30 in wide and 96 in long (minimum)

   (b) Rolled, rounded, sanitary edges, easy to clean

   (c) Construction, type 304 stainless steel, top and legs; top, 18-gage thickness (minimum)

   (d) Three pairs of legs securely fastened to top frame

7. Product mixers

   (a) Portable, variable-speed, 100- to 1,750-r/min, ¼-hp (minimum)

   (b) Shaft and propeller, stainless-steel; shaft length, 30 in (minimum); propeller diameter, about 3¾ in

   (c) Clamp-on mount with adjustment for shaft angle in mixing tank

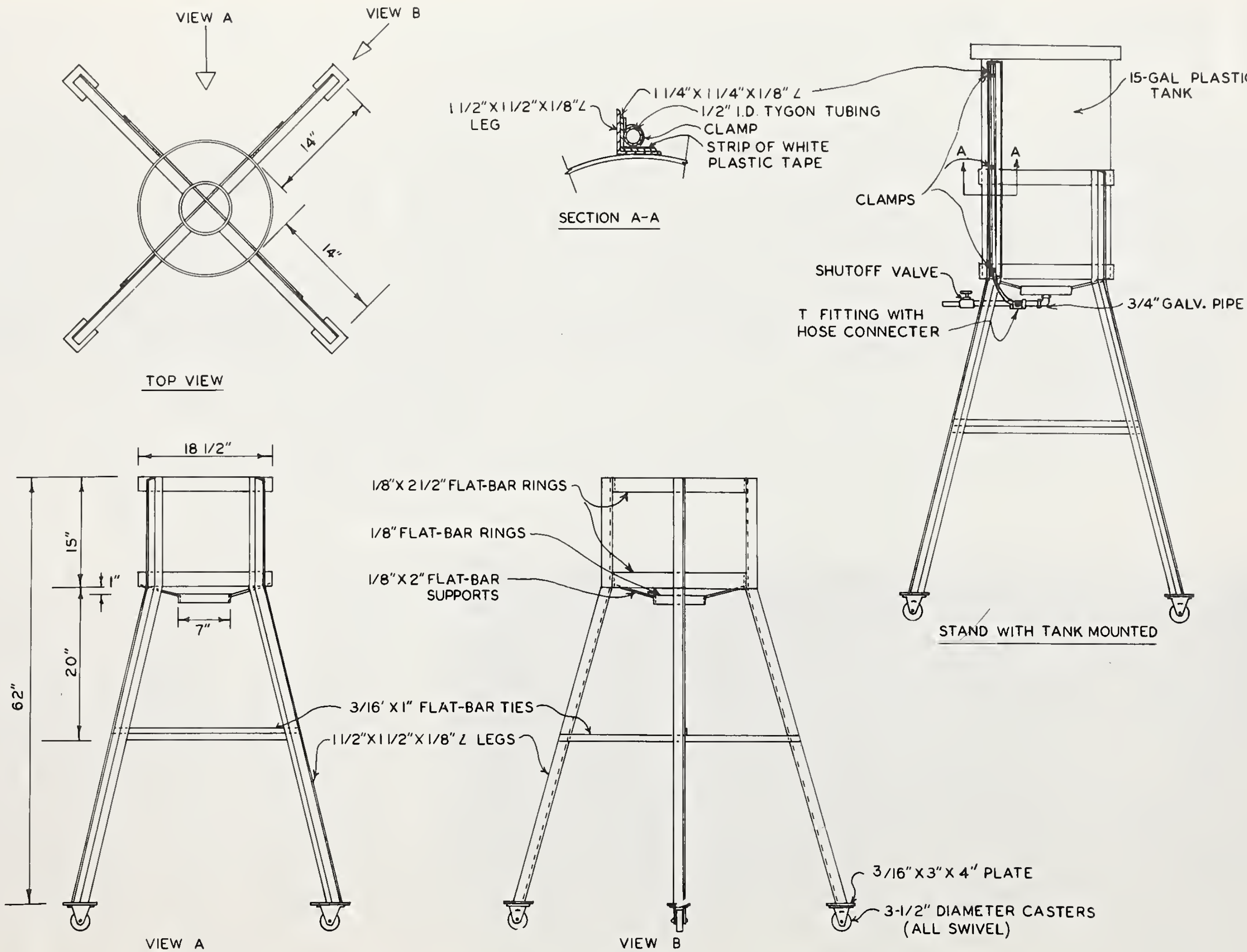


FIGURE 8.—Details of diet-water tank and stand.

(d) Direct-drive; electrically operated, Lightning model NS-1-VM or equivalent; air-operated, Chemineer model APD with air regulator, lubricator, and filter

8. Diet-water measuring tank (fig. 8), if desired, 30 gal, polyethylene; calibrated and marked for measuring quantity of water for various-size batches of diet mix to eliminate weighing of water; ¾-in national-pipe-thread outlet in bottom, ¾-in galvanized pipe with cutoff valve connected to tank through opening; tank mounted on metal frame with four legs on casters, high enough for drain pipe to be above top of diet-mixing tank
9. Steam boiler, steam required for each sterilizer unit; if building has high-pressure (100- to 125-lb/in^2) boiler for other purposes in facility and has sufficient capacity, it may be used to supply steam to sterilizers, but if separate boiler is required, it should meet the following specifications:
   (a) Capacity, 350 lb of steam per hour at 125 lb/in^2
   (b) All safety controls and starters required by local, State, ASTM, ASME, and other codes that have regulating authority in an area
   (c) Operates on gas, electricity or fuel oil, depending on availability of fuel at location
   (d) Supply water, preheater tank, and controls to maintain water at 180° F (minimum)
   (e) Condensate collection and pumping system
   (f) Aluminum or painted 22-gage steel-finished jacket, with 1½-in-thick (minimum) mineral or glass wool insulation material having a density of 3 lb/ft^3 between boiler walls and jacket
   (g) Dual, high-pressure supply water pump for alternate or standby use
   (h) If boiler is required for each sterilizer, it should have capacity of 100 to 125 lb of steam per hour and meet specifications (b) through (g) above.

PELLET-PREPARATION AND STORAGE AREA

This area is located within the main rearing building and should contain a pellet-preparation room, pellet-storage room, equipment cleanup room, dressing room, and restroom with convenient access doors (fig. 9).

The diet pellets are used for both food and oviposition sites for the adults. They are mechanically formed, cut to length, and wax coated by the pellet-making and waxing machines (Griffin and Lindig 1974a, Griffin et al., 1979). Sterile adult-diet material at about 120° F is delivered from the sterilizer to the manifold of the pellet machine through a ⅜-in (o.d.) stainless-steel tube. A valve actuator system (Griffin 1979b) and a cycle timer control, time, and direct the flow of diet from the manifold into the forming tubes of the heat exchanger. In the heat exchanger, water at about 45° F flows around these forming tubes, cools the diet, and causes it to congeal. On the following cycle when more warm diet is delivered to the forming tube, the congealed diet is forced out the discharge end of the tube. A rotating cutoff drum cuts the rods of diet into pellets about ½-in long. These pellets are discharged into the waxing machine, which contains a supply of warm wax. A chain belt elevates the pellets from the wax and deposits them over the end of the wax vat. As the pellets fall into a catching container, a fan blows a blast of air across them to cool and harden the wax coating. The pellets are then placed in pans that are conveyed on carts and stored in a clean storage environment until ready for use. The rotation speed of the cutoff drum can be varied to regulate the length of the pellets. The valve actuator and cycle timer cause the diet to flow intermittently through the forming tubes.

In actual practice, a continuous flow of the diet did not prove satisfactory because it required a longer tube to cool the diet sufficiently to congeal, which caused a separation of the center core and the outer ring of the diet rod and thus produced an inferior pellet. Also, a continuous flow required a pump for each tube of the heat exchanger.

The temperature controller on the wax vat is a proportioning unit and keeps the wax at a near

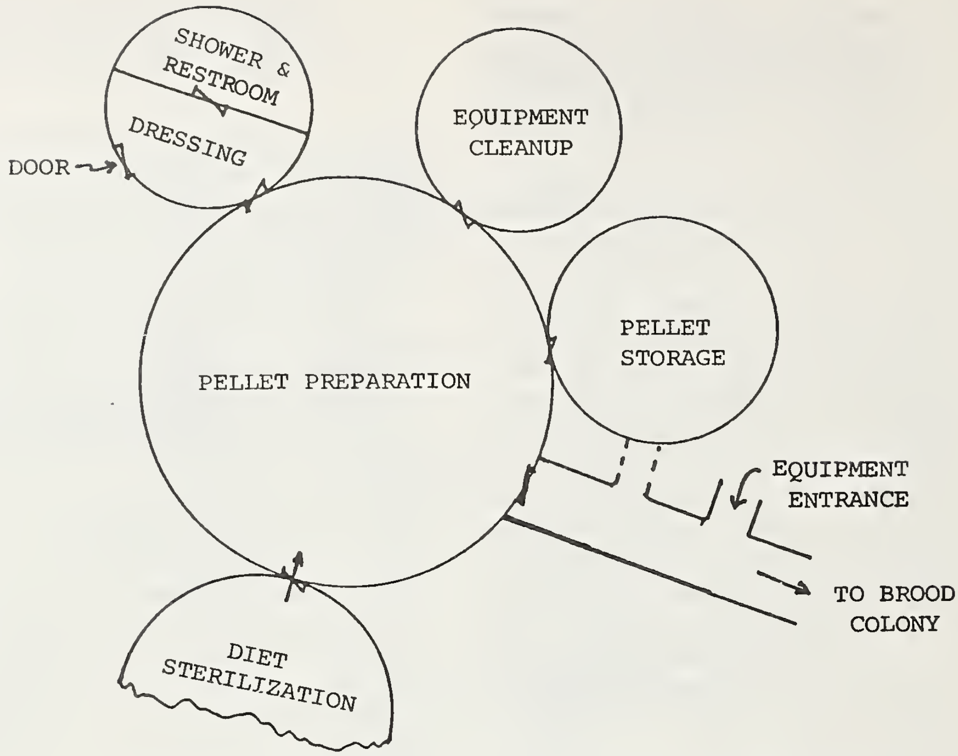


FIGURE 9.—Arrangement of rooms in pellet-preparation and storage area.

constant temperature, which is needed to obtain the proper coat of wax on the pellets. The speed of the elevating belt in the wax vat is important because too high a speed causes the belt to sling wax droplets off by centrifugal force, and too slow a speed allows the wax to cool enough to stick to the chain before discharging into the holding container. A variable-speed drive provides for correct adjustment of belt speed.

Fresh and recycled waxes are mixed and sterilized in the pellet-preparation room. For material-flow efficiency and sanitary precautions, the area should be adjoining or conveniently located near, but not opening directly into, the diet-sterilization and brood-colony areas. Air in the area should be conditioned for human comfort by a separate system and not mixed with or recirculated from any other area. The floor and walls must be cleaned and disinfected; therefore, they must withstand washing and spraying.

SPECIFICATIONS

A. Pellet-preparation room
   1. Size, 24 by 30 by 8 ft (minimum)
   2. Floor, concrete, covered with quarry tile and equipped with drains
   3. Walls, masonry, painted with epoxy enamel
   4. Recessed ceiling lights, wall-switch controlled
   5. Duplex wall receptacles, weatherproof, single-phase, 60-Hz, 120-V, spaced about 8 ft apart with only three per 20-A circuit
   6. Ceiling receptacles, drop-cord, single-phase, 60-Hz, 208- or 230-V, 20-A (two each); and ceiling receptacle, drop-cord, single-phase, 60-Hz, 120-V, 20-A over waxing machine for heaters and elevating-belt motor of waxing machine
   7. Ceiling receptacles, drop-cord, single-phase, 60-Hz, 120-V (two each), over each pellet-making machine for air valves and cutoff-drum motor
   8. Receptacles, cold-water and general-purpose, for each wax-warmer unit; 3-phase, 60-Hz, 208- or 230-V, 40-A
   9. Steam supply, 40 lb/in^2, and condensate drain lines at location of steam kettle used for sterilizing wax
   10. Water-cooler fountain accessible
   11. Air supply, 30 lb/in^2, near air valves on pellet-making machine

12. Water supply, 44° ± 2° F at 8 to 10 gal/min, for each pellet-making machine
13. Air conditioned for human comfort; supply air into room filtered with HEPA filters 99.97% efficient with particles 0.3 μm or larger
14. Entrance door, 3½ by 7 ft (minimum)

B. Pellet storage room
  1. Size, about 8 by 8 ft, with 3½- by 7-ft door
  2. Construction of floor, walls, and ceiling same as those for pellet-preparation room
  3. Recessed ceiling light, wall-switch controlled
  4. Duplex wall receptacles (two each, minimum), weatherproof; single-phase, 60-Hz, 120-V
  5. Air conditioned for human comfort; supply air into room filtered with HEPA filters

C. Equipment cleanup room
  1. Size, about 8 by 8 ft, with 3- by 7-ft door (minimum)
  2. Walls and floor, ceramic-tile, with waterproof pan and drain in floor
  3. Single-compartment plastic tank, about 24 by 60 by 20 in, with drain, mounted on metal base and installed along one of walls for cleaning pans and parts of waxer
  4. Drain from tank to empty into grease or wax trap before entering connection to main-building drainage system; trap to have removable cover and be conveniently located for easy removal of wax accumulation
  5. Faucet for hot- and cold-water mixing, with hose connection over tank
  6. Exhaust fan vented through roof to remove moist air to outside, wall-switch controlled
  7. Ceiling-light fixture, vaporproof, wall-switch controlled

D. Equipment
  1. Pellet-making machine (figs. 10-16)
    (a) Fabricated according to plans shown in figures 10-13
    (b) Valve-controlling air cylinders with 1-in bore, 3-in stroke, and clevis connection
    (c) Four-way air valves, Humphrey model 125-4EI-21-35-CD-70 or equivalent, mounted on common manifold, Humphrey model TM 12 or equivalent
    (d) Continuous cycling timer, Industrial Timer Corp. model MC-4 or equiva-

(*Continued on page 23.*)

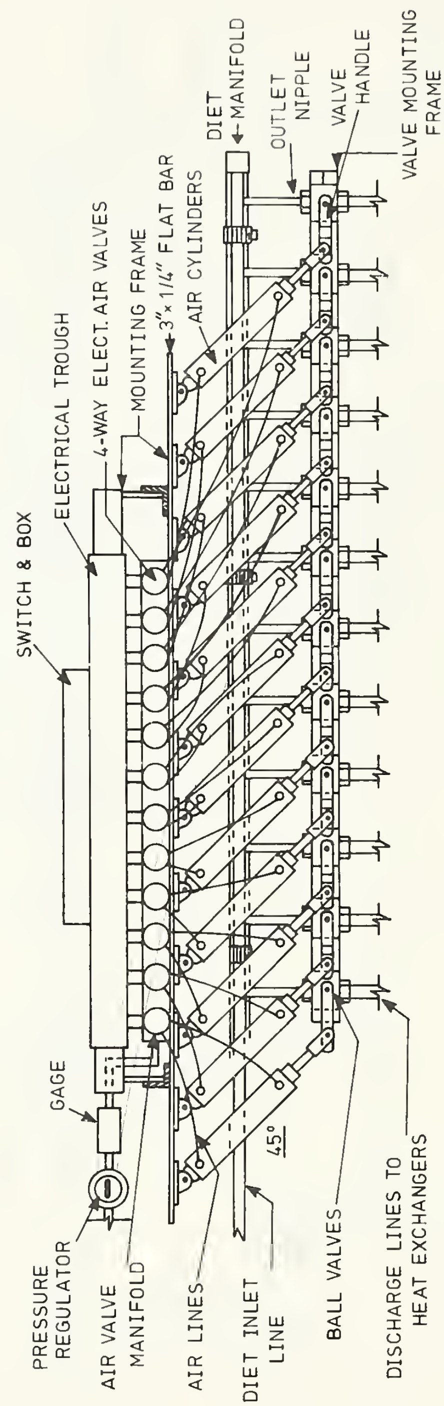


FIGURE 10.—Schematic diagram showing top view of automatic nozzle actuator for pellet machine.

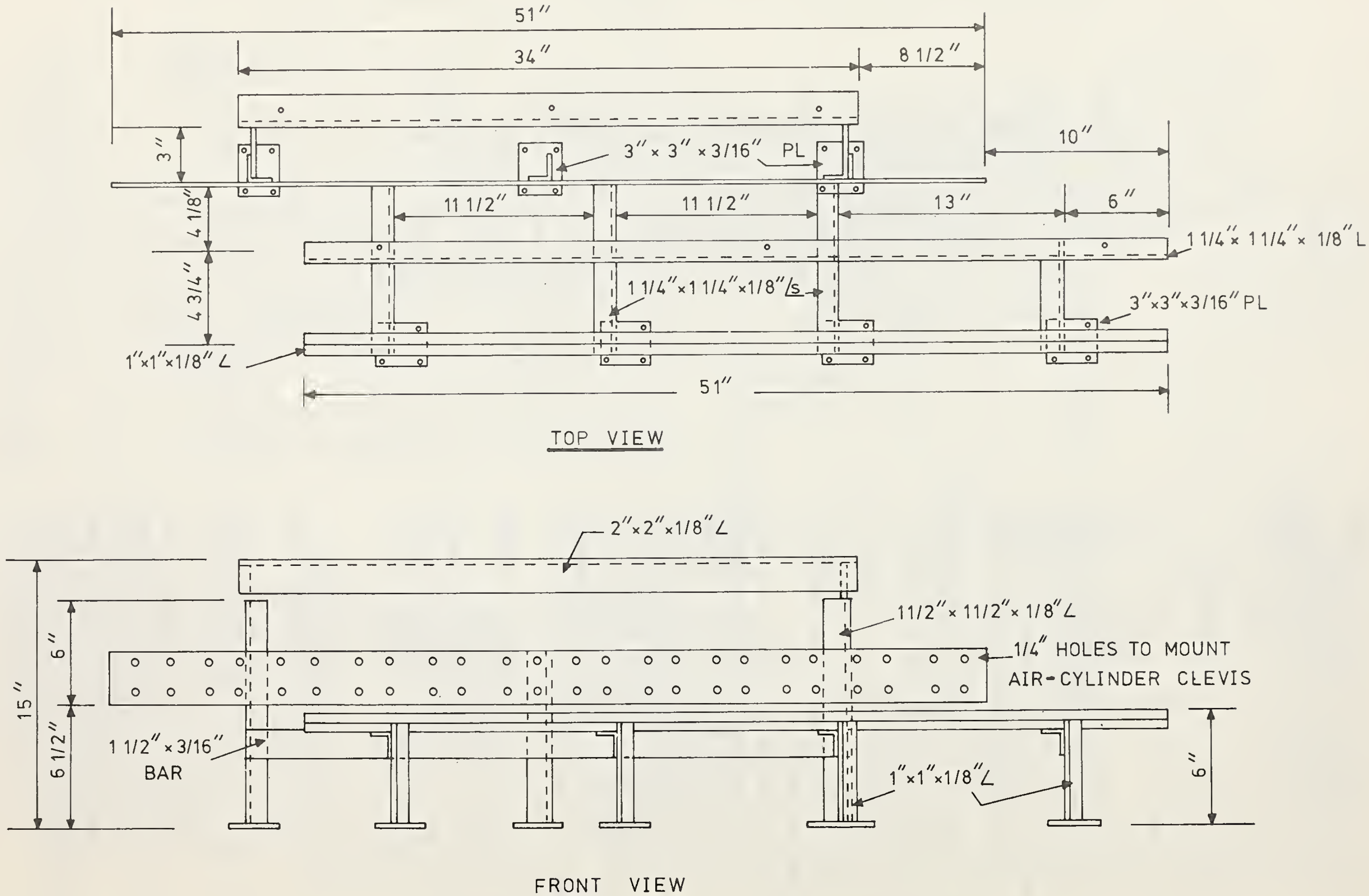


FIGURE 11.—Details of mounting frame for valve-actuator system.

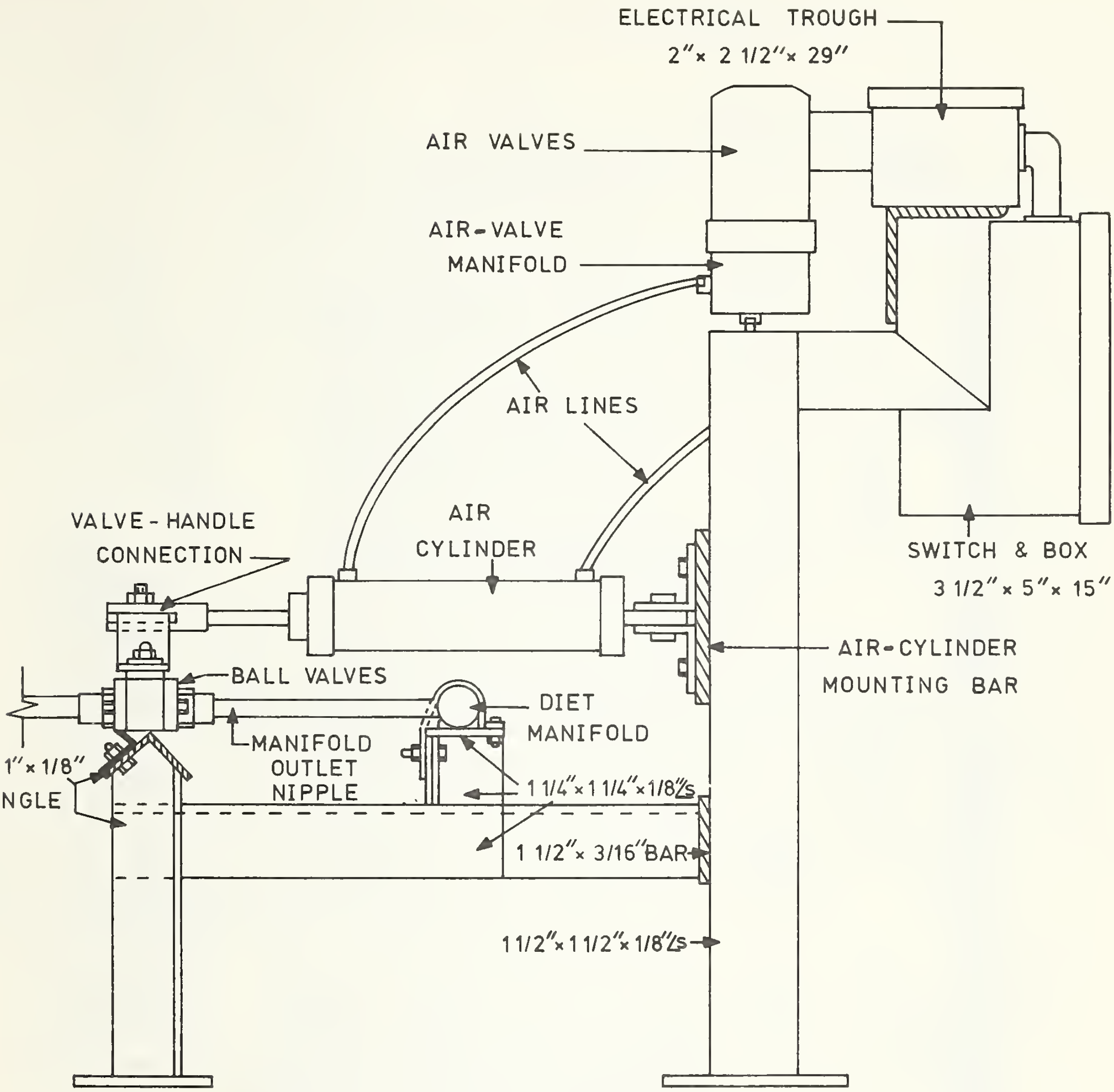


FIGURE 12.—Schematic diagram showing end view of valve-actuator system.

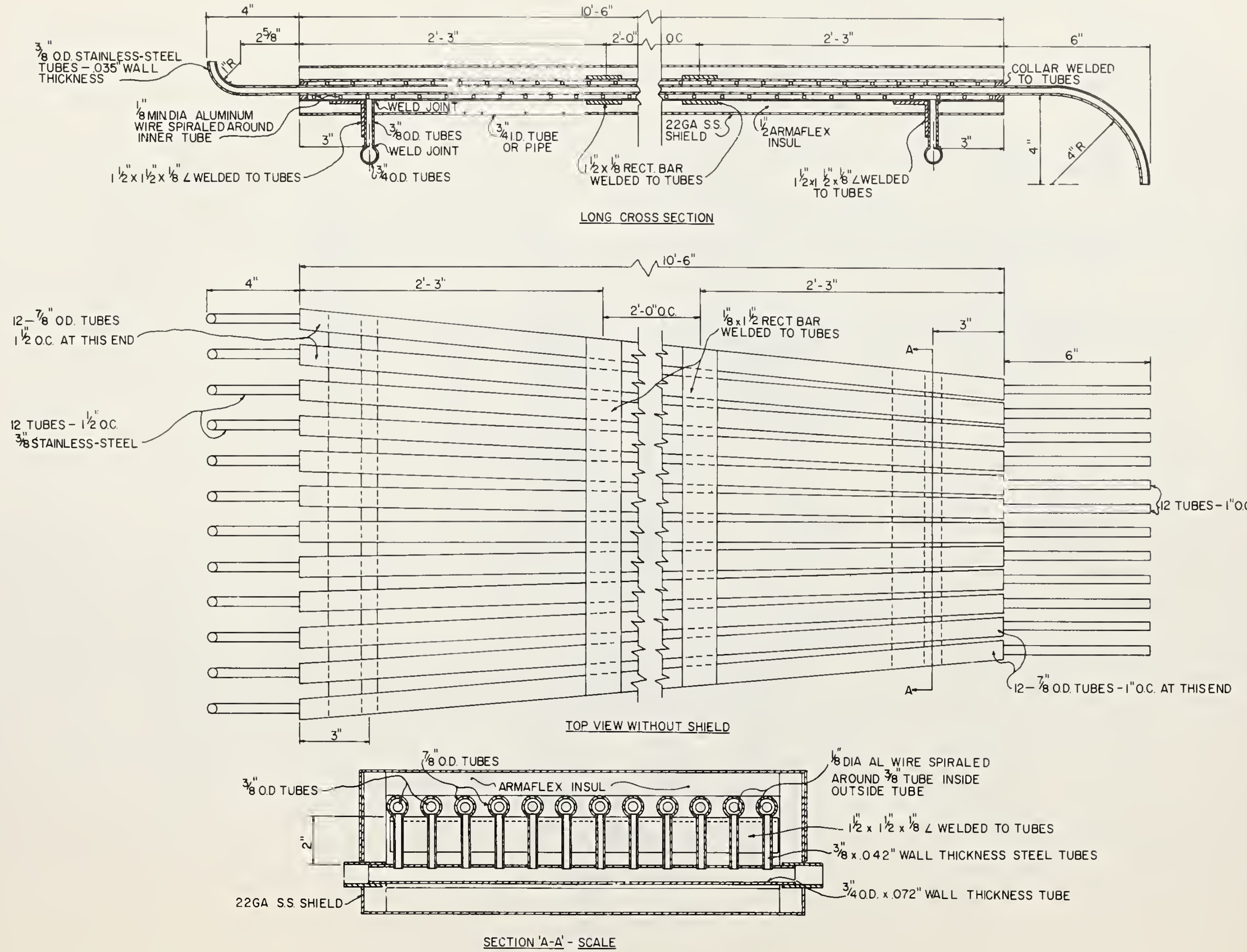


FIGURE 13.—Details of pellet-machine heat exchange system.

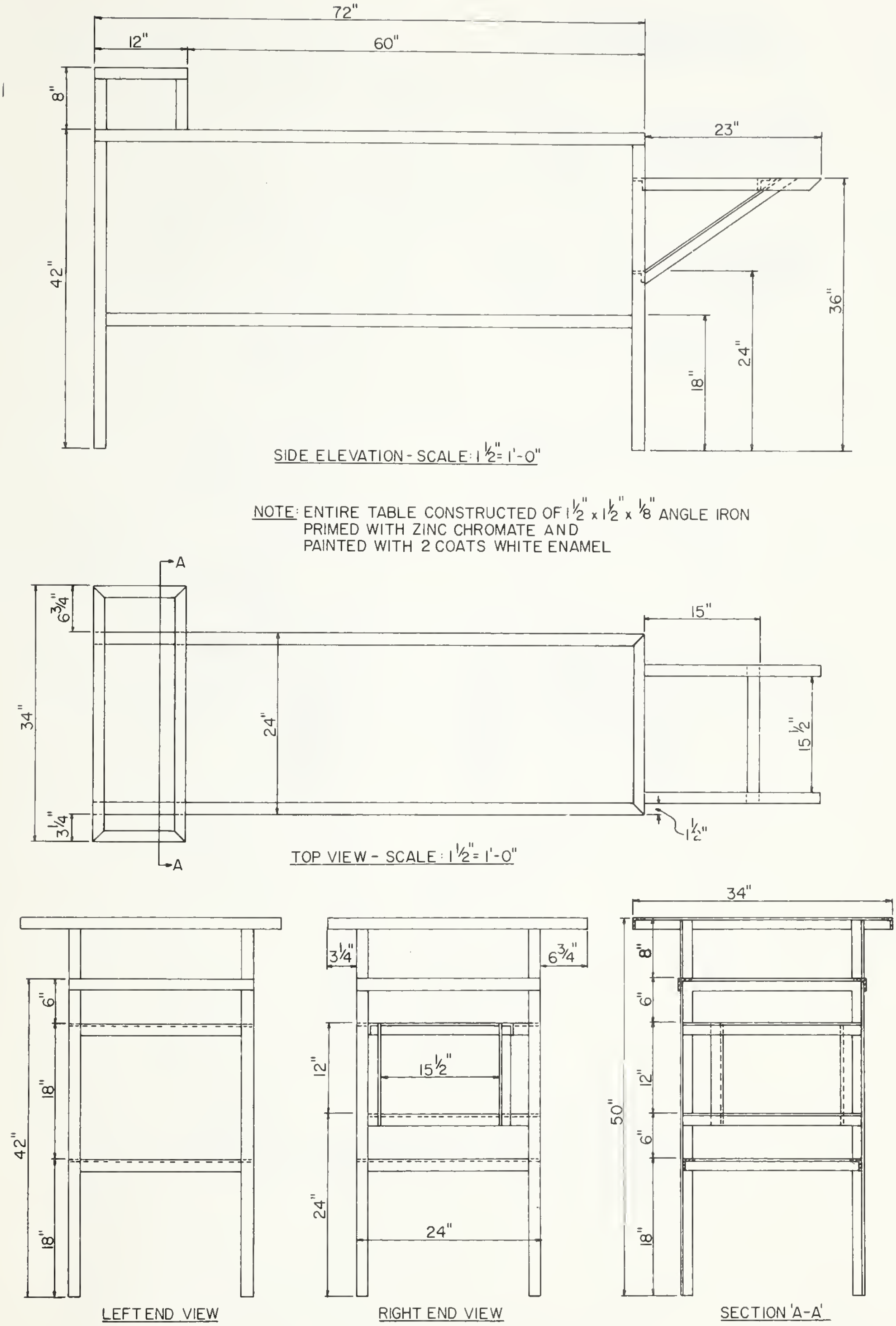


FIGURE 14.—Details of pellet-machine stand.

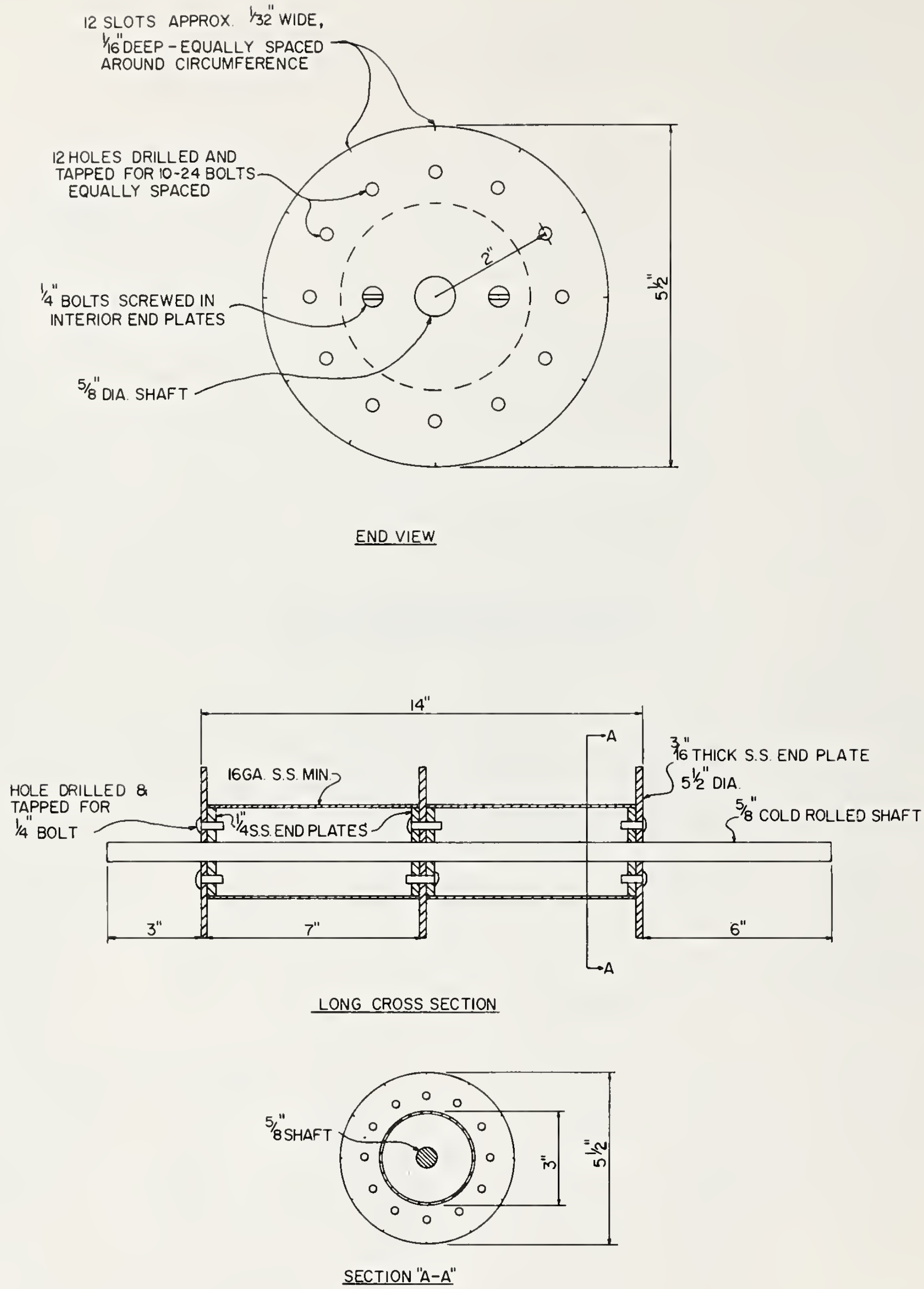


FIGURE 15.—Details of pellet-machine cutoff drum.

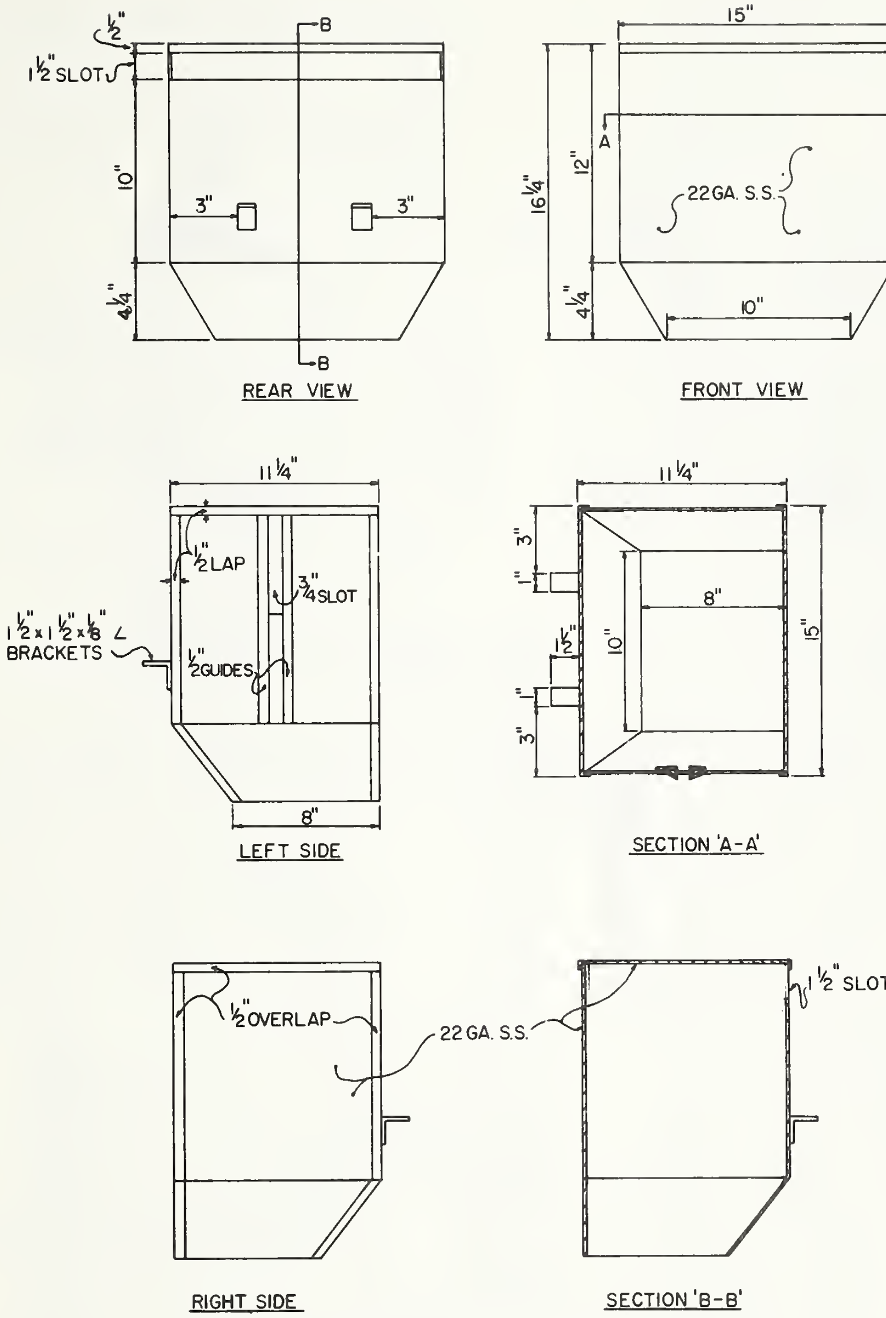


FIGURE 16.—Details of pellet-machine cutoff drum shield.

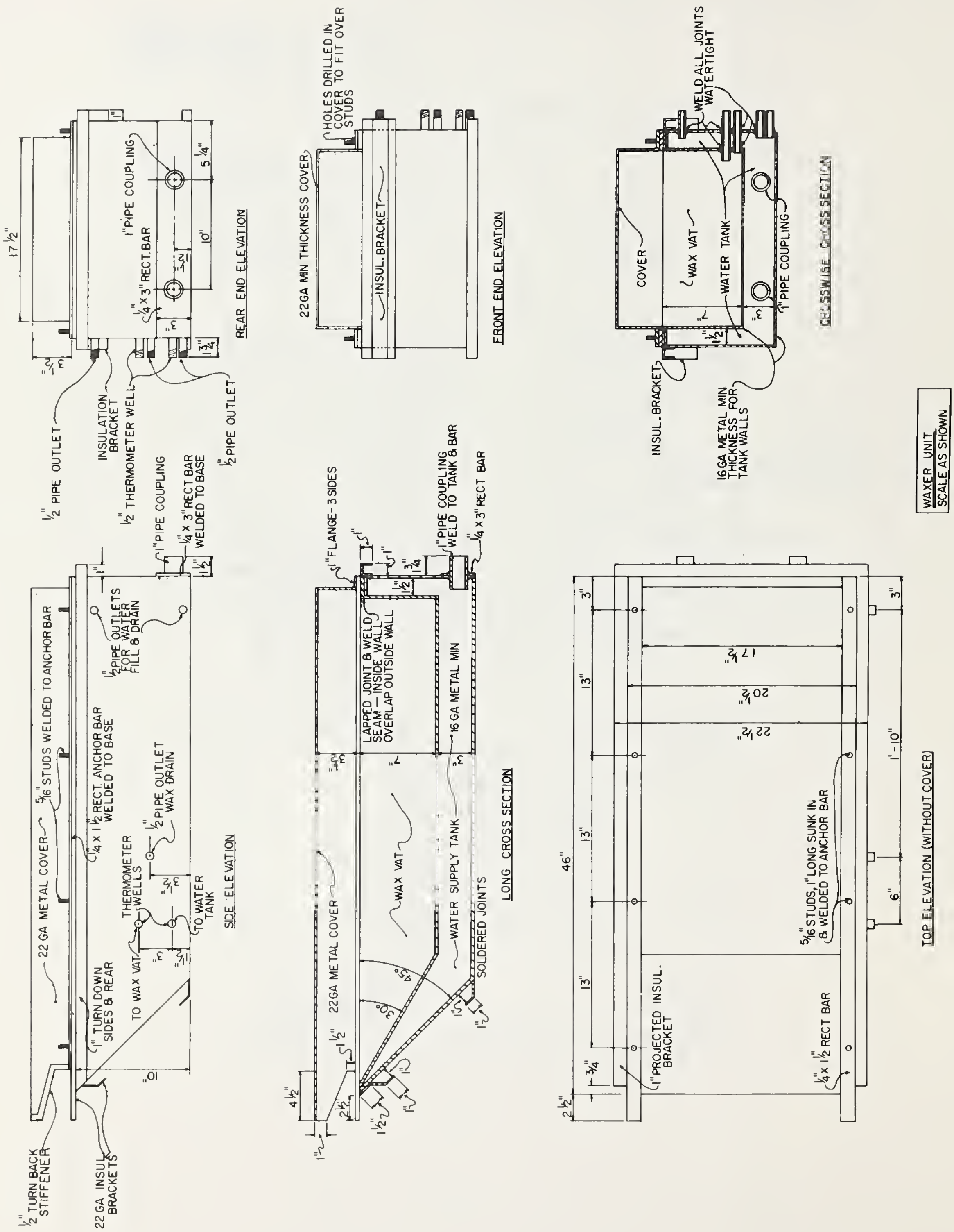


FIGURE 17.—Details of waxing machine.

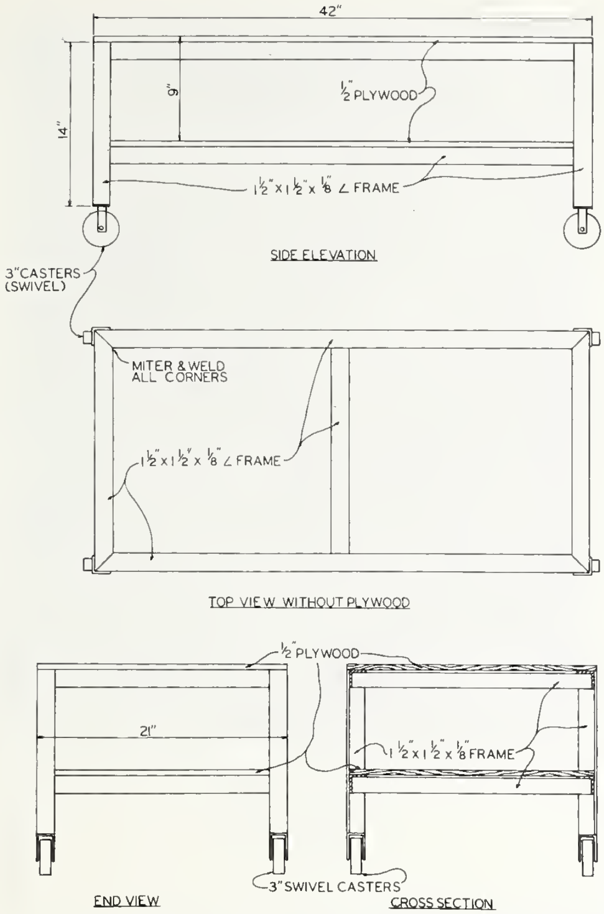


FIGURE 18.—Details of waxing-machine stand.

lent, 12 cams and switch, 40-s cycle; operates air valves

(e) Gearmotor, Dayton, variable-speed, 100-r/min, 1/15-hp a.c.-d.c. (minimum), with variable-speed control switch

2. Waxing machine, places thin coat of wax material on surface of diet pellets
   (a) Fabricated according to plans in figures 17-19
   (b) Heater elements (two each), immersion-type, 2,500-W, single-phase, 60-Hz, 230-V
   (c) Proportioning-temperature controller, RFL Industries, Inc. model 70/230V, with sensor No. 27687-3 (20° to 250° F) or equivalent; automatically controls temperature of water bath
   (d) Vat insulated with 1-in-thick-fiberglass rigid-board insulation
   (e) Elevating wire belt, Wire Belt Co. of America Belt No. 422 or equivalent, constructed of stainless-steel, ¼-in-mesh, 0.035-in-wire, 14-in-wide, seven-space wire-belting material; also included are matching drive gears and blanks
   (f) Motor, Zero Max or equivalent, totally enclosed, fan-cooled, ¼-hp, 1,725-r/min, single-phase, 60-Hz, 120-V, with variable-speed reducer drive; drives elevating wire belt
   (g) Vat and cover, made of type 304 stainless steel
   (h) Stand frame, made of stainless steel
   (i) Exterior-grade plywood for stand top and shelf, painted with three coats of epoxy enamel
3. Wax warmers (fig. 20), Groen model EE-40 or equivalent, two units maintain wax at proper temperature for use in waxer
   (a) Capacity, 40 gal, with cover
   (b) Kettle, electric, self-contained, steam-jacketed, with adjustable automatic temperature control
   (c) Construction of interior and exterior, stainless steel
   (d) Fully insulated between interior kettle and exterior shell
   (e) Tangent-type drawoff line with compression disk-type drain valve
   (f) One-piece dome cover with counterbalance actuator
   (g) Meets ASME codes
   (h) Controls to include thermostatic switch, pressure gage, pressure-limit control, water-valve gage, safety valve, low-water cutoff, and pilot light
4. Steam kettle, Legion Equipment Co., Inc., or equivalent
   (a) Tank, 80-gal capacity; two-thirds jacketed, 18-8 composition, type 304 stainless steel
   (b) Tangent-type drawoff line with compression disk-type drain valve
   (c) Steam pressure, 40 lb/in^2
   (d) Construction meets all ASTM and ASME codes
   (e) Dome cover, hinged
   (f) Legs, tubular-steel, enameled
   (g) Popoff safety relief valve, steam-pressure regulator and steam trap included

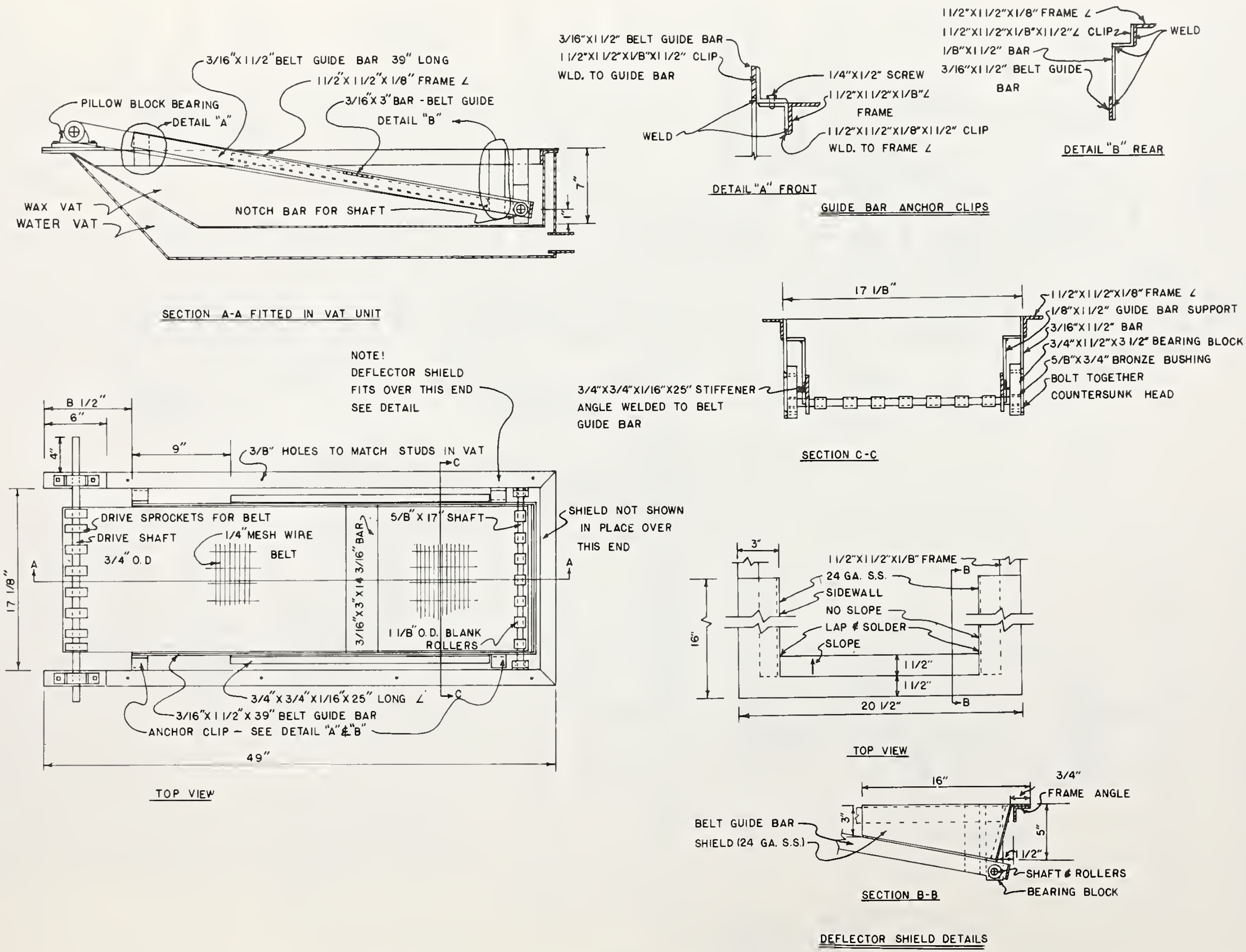


FIGURE 19.—Details of elevating wire belt for waxing machine.

FIGURE 20.—Wax warmer for maintaining wax at proper temperature.

5. Pellet-collecting bins and dollies
   (a) Units (two each) made according to plans in figure 21
   (b) Bins made of 20-gage, type 304 stainless steel with ½-in turndown rim
   (c) Size, 16 by 28 by 9 in (minimum)
   (d) Dollies, made of 1½- by 1½- by ⅛-in stainless-steel angle with four 2½-in-diameter roller-bearing casters
6. Waste container, Adcraft No. 3637 or equivalent, used to catch waste and cleaning solution during cleaning and sanitizing of pellet machine
   (a) Capacity, 45 gal (minimum); construction, heavy-duty
   (b) Tank made of polyethylene and mounted on marine-plywood solid base with four casters
   (c) Unit to have bottom drain assembly
   (d) Load capacity, 200 lb
7. Pellet-storage pans, pellets removed from collecting bins (fig. 21) and stored in pans until fed to boll weevils
   (a) Construction, linear polyethylene
   (b) Size, about 12 by 18 by 7 in
   (c) Matching cover to fit pan
8. Pan-storage cart, Admiral Craft model 259 or equivalent; pans of pellets stored on and conveyed by the cart
   (a) Pan and tray rack, standard stainless steel, 68½ in high, with 12 shelf brackets spaced 5 in on center, for 18- by 26-in trays
   (b) Construction, heavy-duty
   (c) Unit mounted on four 5-in-diameter caster wheels with neoprene tires
9. Pan-filling stand, pellet pans placed on stainless-steel stand (fig. 22) while being filled
10. Water cooler, used to cool water (45° F) for pellet-making machine (fig. 23) if cold-water supply for air-conditioning system of building is not used for this purpose
    (a) Compressor-condenser unit, 2-ton cooling capacity per pellet-making machine
    (b) Water-holding tank, 40-gal capacity per pellet-making machine; insulated with ½-in-thick Armaflex (Armstrong Co.) plus 1½-in-thick glass material or equivalent; metal jacket to cover insulation
    (c) Water-chiller unit, Inner-Fin, 2-ton capacity, with heavy insulation and metal outer shell
    (d) Thermostat sensor, located in water-holding tank to maintain water at 42° ± 3° F; thermostat controls compressor and water-circulating pump for liquid-chiller unit
    (e) Water-circulating pump, Teel Dayton No. 1P787 or equivalent, supplies water to pellet-making machine for delivering 10 gal/min (minimum) at 20-lb/in^2 head
    (f) All cold-water pipes covered with ¾-in-thick Armaflex or equivalent
    (g) On-off switch, located on pellet machine to control pump motor for circulating water to machine

(*Continued on page 28.*)

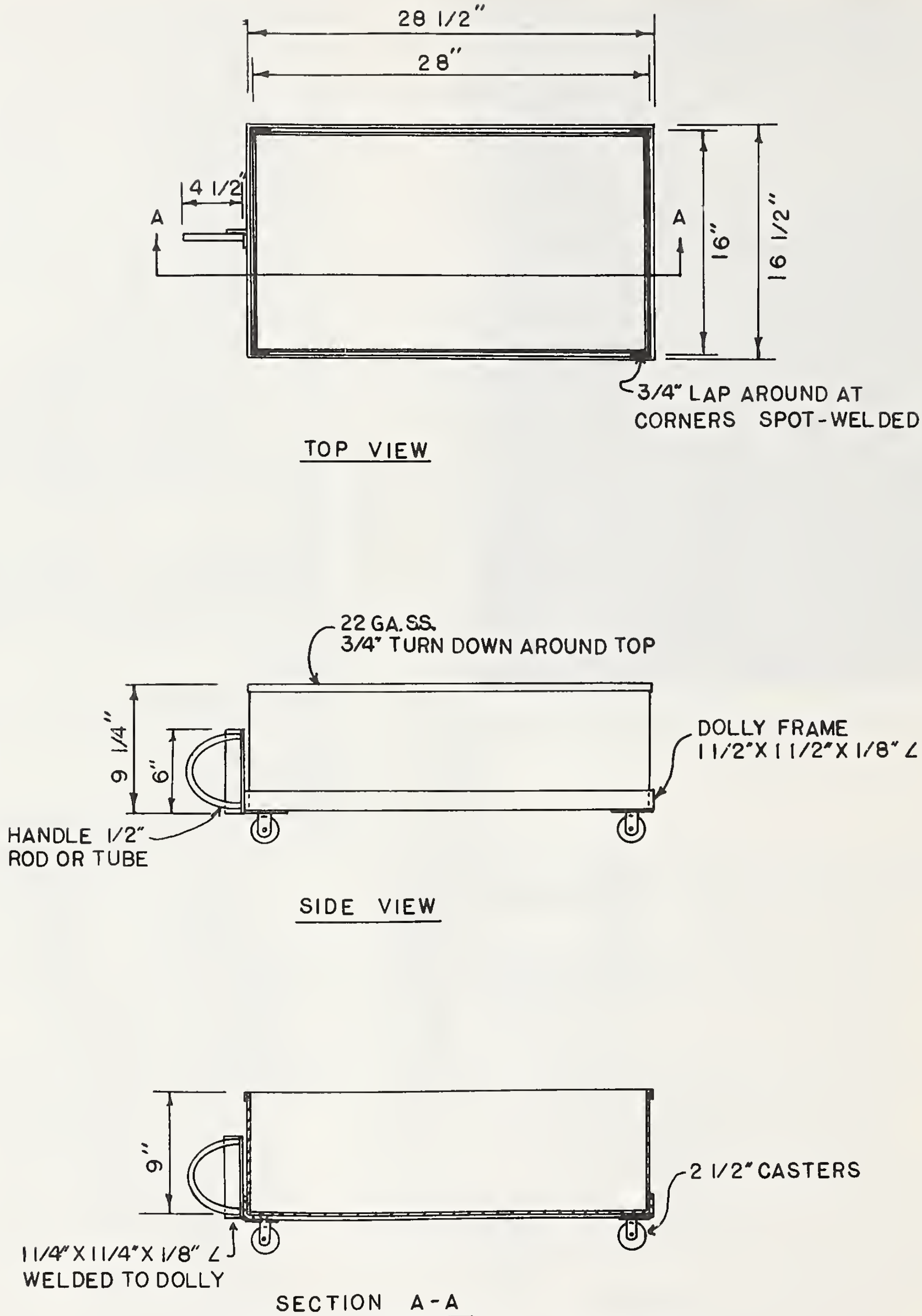


FIGURE 21.—Details of pellet-collecting bin and dolly.

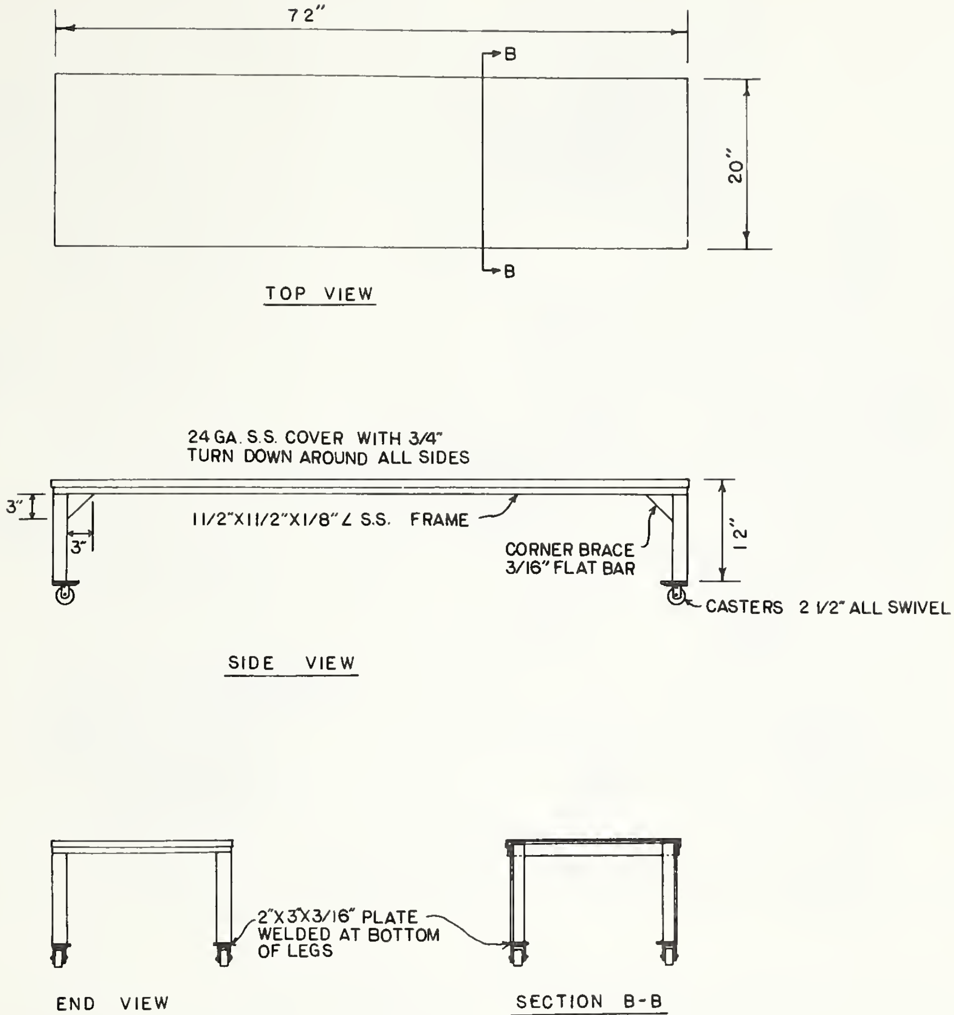


FIGURE 22.—Details of pellet pan-filling stand.

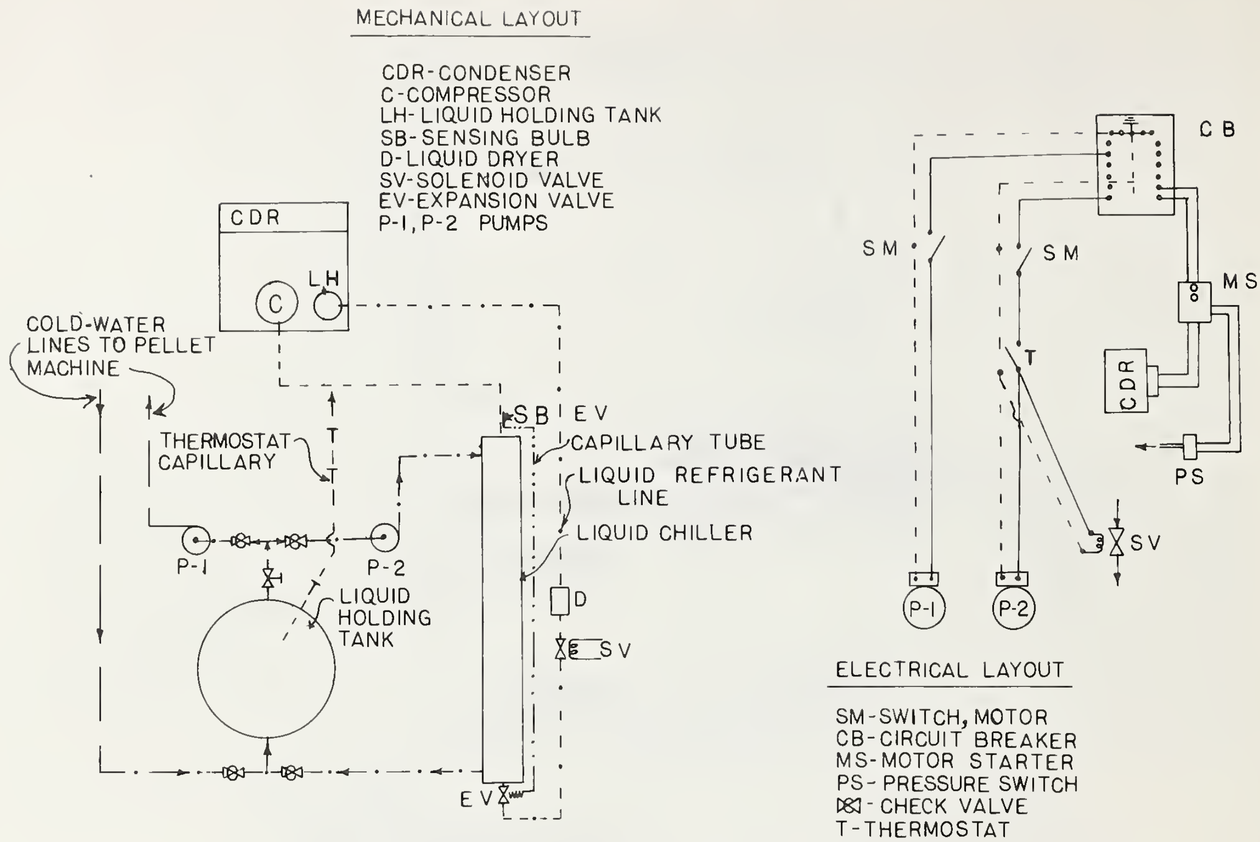


FIGURE 23.—Schematic diagram of water-cooling system for pellet machine.

BROOD-COLONY AREA

This area contains oviposition room, equipment cleanup and storage rooms, cage-preparation room, dressing room, and restroom (fig. 24).

Mixed sexes of boll weevils for egg production are held in cages during the ovipositing period. Once each day the old pellets infested with eggs are removed and fresh pellets are added to the cages (Griffin 1979f, Griffin et al. 1979).

The cage-preparation room should be the central point of the area, with doors opening to the other rooms or areas, including the pellet-making and emergence areas. The other rooms do not have connecting doors. The only access to the restroom is through the dressing room, which connects to the cage-preparation room. Outside access to the area is through the dressing room. The cage-preparroom, equipment cleanup and storage rooms, dressing room, and restroom can be combined for similar uses in the emergence area (fig. 25). The oviposition room requires a separate air-conditioning system to maintain a controlled environment (86°±2° F and 40%±3% RH) that must be uniform throughout the room. Sanitation is also important, especially in the oviposition room. Air from the other rooms of the area or any other areas of the facility should not be circulated into this room. A human-comfort environment is satisfactory in other rooms of the area, which should be kept as clean as possible.

The equipment storage room is used to store extra cages from the time they are washed and sanitized until they are used again. If proper area layout for the rearing building is followed, increasing the size of this room would allow it to serve as a storage room for the extra emergence cabinets.

The production equipment used in the brood-colony area includes oviposition cages, cage conveyors, cage shakers, balances, tray truck, and washing tank (Griffin 1979f, Griffin et al. 1979).

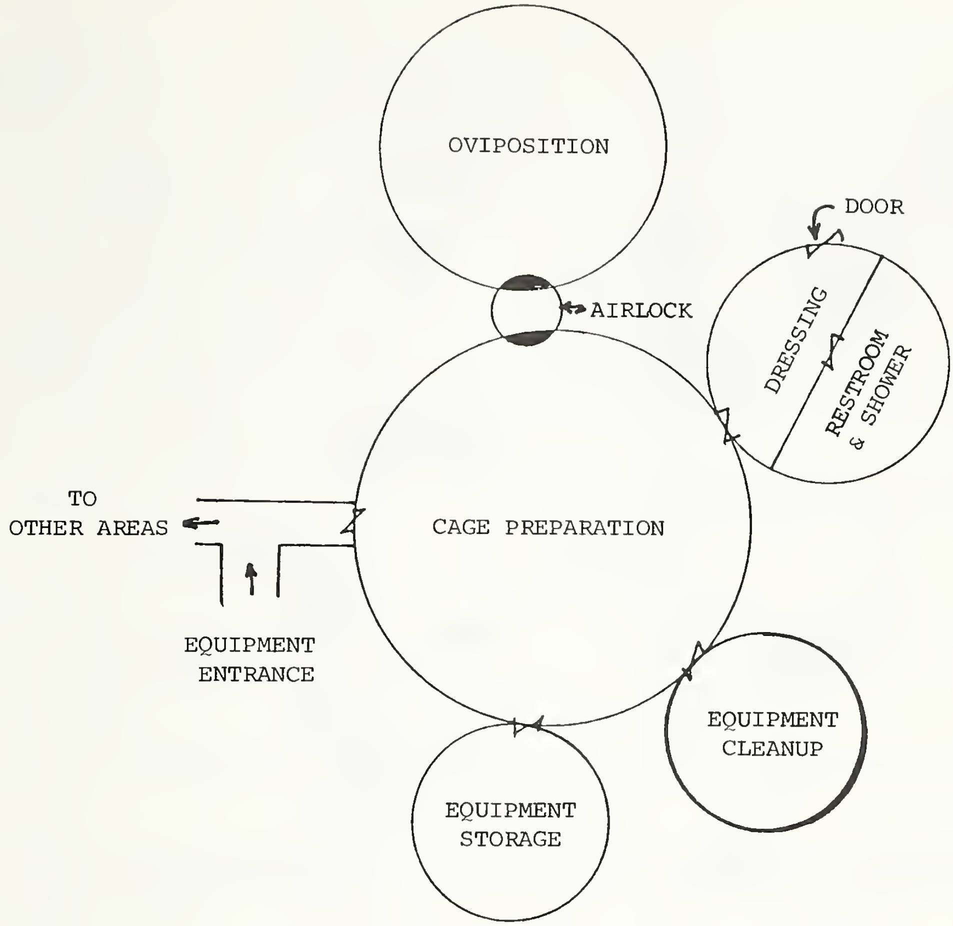


FIGURE 24.—Arrangement of rooms in brood-colony area.

SPECIFICATIONS

A. Oviposition room
   1. Size, about 28 by 40 ft, with 9-ft ceiling
   2. Floor, concrete, with broken quarry-tile cover and drain with cap
   3. Walls, masonry, painted with epoxy enamel; exterior walls insulated
   4. Ceiling light fixtures, recessed, insect-proof, wall-switch controlled
   5. Duplex receptacles, weatherproof, wall-mounted about 10 ft apart, maximum of three per 20-A circuit; single-phase, 60-Hz, 120-V
   6. Switch and receptacle boxes, located so as not to be in same wall cavity with boxes of adjoining rooms
   7. Air-conditioning equipment and controls to maintain temperature of 86°±2°F and RH of 40%±3%, with proper air movement to reduce temperature and RH stratification between ceiling and floor levels to minimum; separate air-conditioning unit to prevent any mixing of air between this and any other room
   8. Moisture input into room from pellets and boll weevils, 15 to 17 lb/h; very little heat input per hour from boll weevils
   9. Door between room and cage-preparation room, 3½ by 7 ft
   10. Windows not required, room to remain dark except when feeding boll weevils and cleaning equipment or room
   11. Fresh-air intake, about 4% of volume of room per minute filtered by HEPA filter before entering air-conditioning system

B. Equipment-cleanup room
   1. Size, 12 by 12 ft (minimum); with right

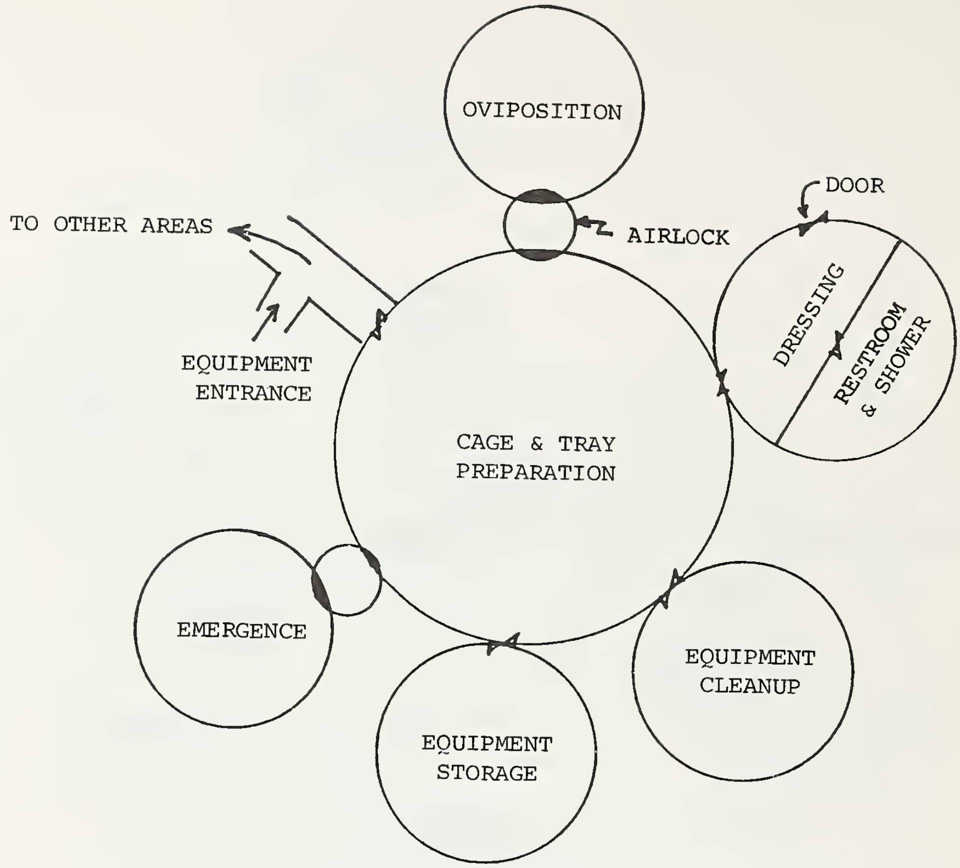


FIGURE 25.—Arrangement of rooms when brood-colony and adult-emergence areas are combined.

floor layout room could also be used for cleanup room for emergence area
2. Floor, concrete, with ceramic-tile cover, waterproof pan, and drain
3. Walls, masonry, with ceramic-tile cover
4. Waterproof board and cover for ceiling
5. Light fixture, vaporproof, wall-switch controlled
6. Exhaust fan vented through roof
7. Metal door, 3½ by 7 ft, 1¾ in thick, with some glass area and louvered vent section near floor line.
8. Hot- and cold-water source with water hose attached to faucets over wash tank

C. Cage-preparation room
1. Size, 12 by 24 ft (minimum); 16 by 24 ft if used in combination with emergence area
2. Floor, concrete, with broken quarry-tile cover
3. Walls, masonry, painted with epoxy enamel
4. Ceiling, gypsum-board
5. Recessed ceiling lights, wall-switch controlled
6. Duplex receptacles, weatherproof, wall-mounted not more than 10 ft apart, two per 20-A circuit; single-phase, 60-Hz, 120-V
7. Doors to other adjoining rooms, 3½ by 7 ft, 1¾-in-thick metal
8. Air conditioned for human comfort

D. Equipment-storage room
1. Size, 12 by 12 by 8 ft (minimum); 12 by 16 by 8 ft if also used for storage of extra emergence cabinets
2. Floor, concrete base, with sealer or broken quarry-tile cover
3. Walls, masonry, painted with epoxy enamel
4. Ceiling, gypsum-board, finished smooth and painted with epoxy enamel
5. Door, 4 by 7 ft, with small glass area, opening to tray-preparation room
6. Window optional; if used install stationary panel

E. Dressing room and restroom
1. An air exhaust should be located in this

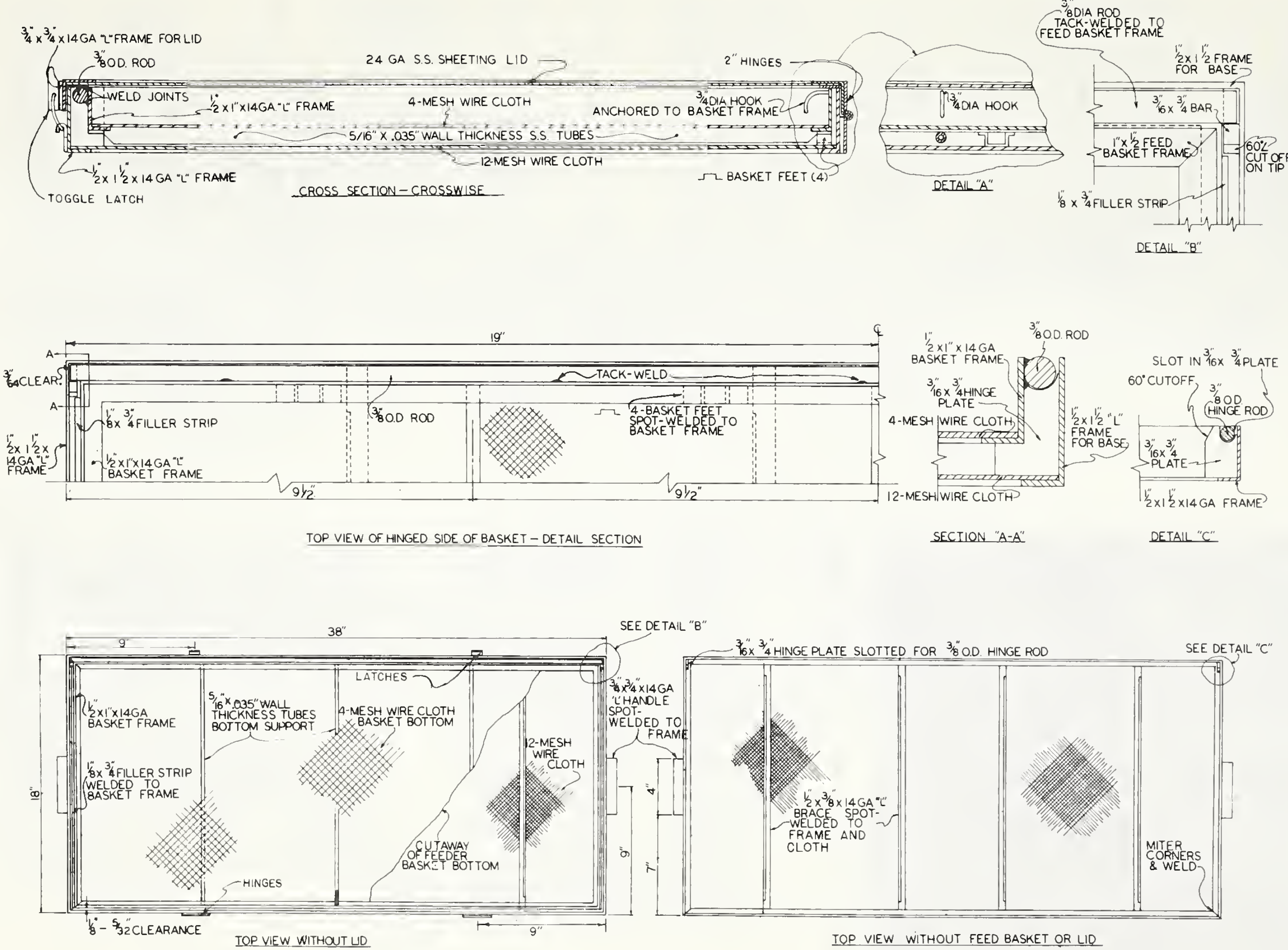


FIGURE 26.—Details of oviposition cage.

FIGURE 27.—Oviposition-cage conveyor and shaker.

section and vented through roof

2. Dressing room, 8 by 10 ft (minimum), with concrete floor, gypsum-board ceiling, and masonry walls painted with epoxy enamel
3. Restroom, concrete floor; lavatory with mirror and light above; commode enclosed in metal stall; metal door, 2½ by 6⅔ ft (minimum)
4. Shower stall, 6 by 6 ft (minimum); four shower heads; ceramic-tile walls and floor; floor covered with waterproof pan; floor drain

F. Equipment
1. Oviposition cage (fig. 26)
   (a) All material (except weatherstrip) stainless steel to withstand disinfectants
   (b) Weather-stripping material, closed-cell neoprene bonded to metal, with appropriate adhesive to withstand washing in water
2. Cage conveyor, Speed Check Conveyor Co., Inc., 25-basket model or equivalent (fig. 27), used to hold and convey cages of boll weevils to feeding station
   (a) Minimum of 25 baskets, with six shelves spaced 6 in apart
   (b) Unit operates on single phase, 60 Hz, 120 V
   (c) Motor with reversing switch, drives conveyor in either direction
   (d) Baskets and shelves modified as follows:
      (1) ½-in rod bent in a U-shape and welded to sidewalls and bottom of each shelf to extend support depth of shelf to 26 in
      (2) ½-in rod placed across basket about 3 in above bottom near rear and welded to rods of sidewalls to prevent cage from tilting forward and falling from basket
3. Cage shaker, used to shake cages at feeding time to separate boll weevils and old food pellets (Griffin et al. 1979)
   (a) Unit constructed according to plans in figure 28
   (b) Metal frame members, primed with zinc chromate and painted with three coats of rust-resistant metal enamel
4. Balances, Mettler model P5N or equivalent, used to weigh boll weevils for getting correct number to place in cages and for other purposes
   (a) Top-loading type
   (b) Capacity, 5 kg, adjustable in 500-g increments.
   (c) Tare-weight adjustment
   (d) Provision for leveling unit with visible leveling bubble
   (e) Light for illuminating dial, with on-off switch; dial division, 1 g or less; operates on single phase, 60 Hz, 120 V
5. Tray truck, Admiral model 445 or equivalent
   (a) Shelves (four each), about 21 by 35 in, with turned-down edges
   (b) Overall height, about 45 in
   (c) Wheels, 5-in-fixed (two each) and 5-in-swivel (two each)
   (d) Construction, stainless-steel
6. Washing tank
   (a) Single-compartment plastic tank, about 24 by 60 by 20 in, with drain
   (b) Metal stand to support tank, shop-fabricated, height to make top of tank about 32 in from floor level
   (c) Grease- or wax-trap unit installed in drain of tank to remove trapped wax

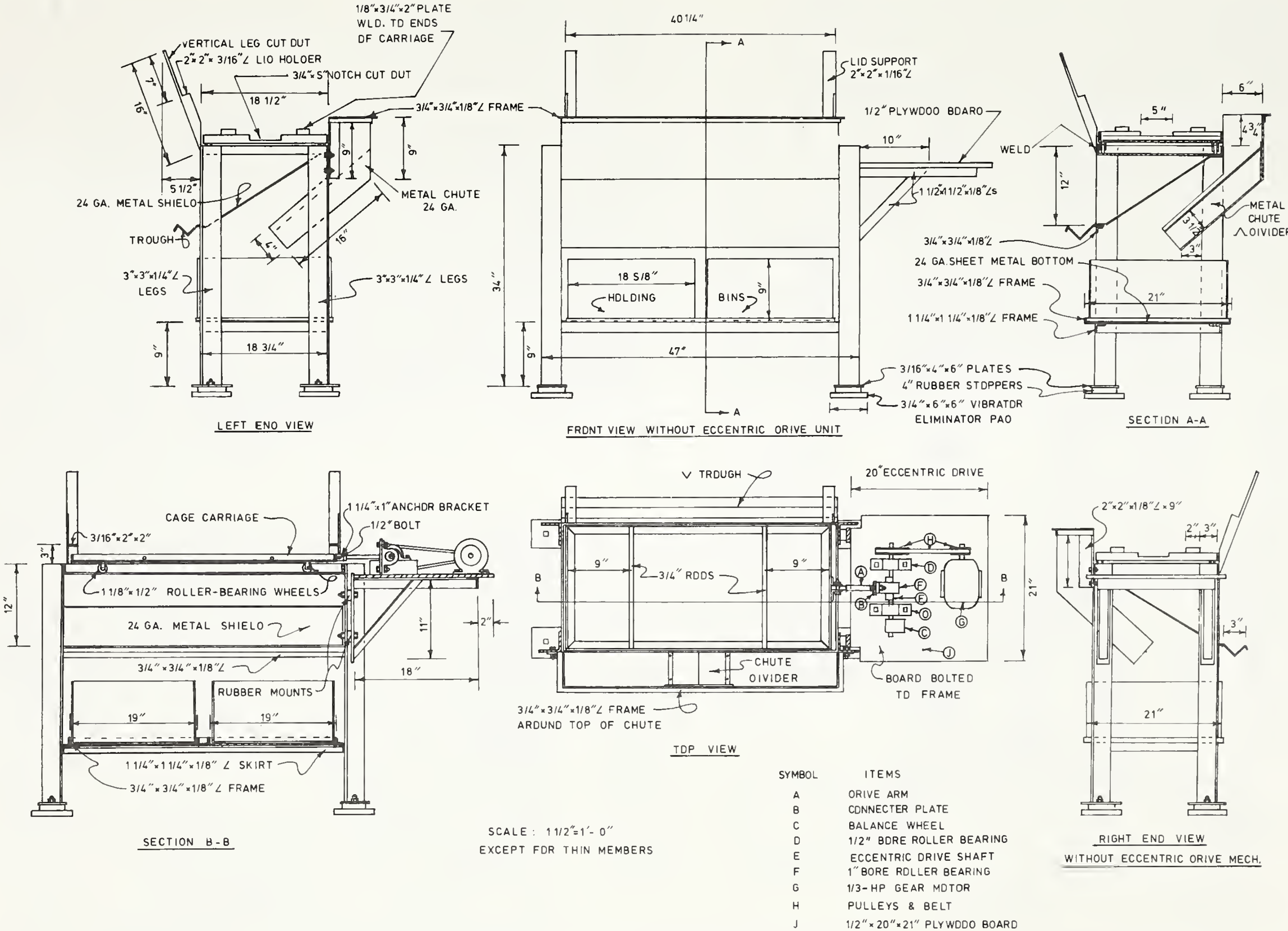


FIGURE 28.—Details of oviposition-cage shaker.

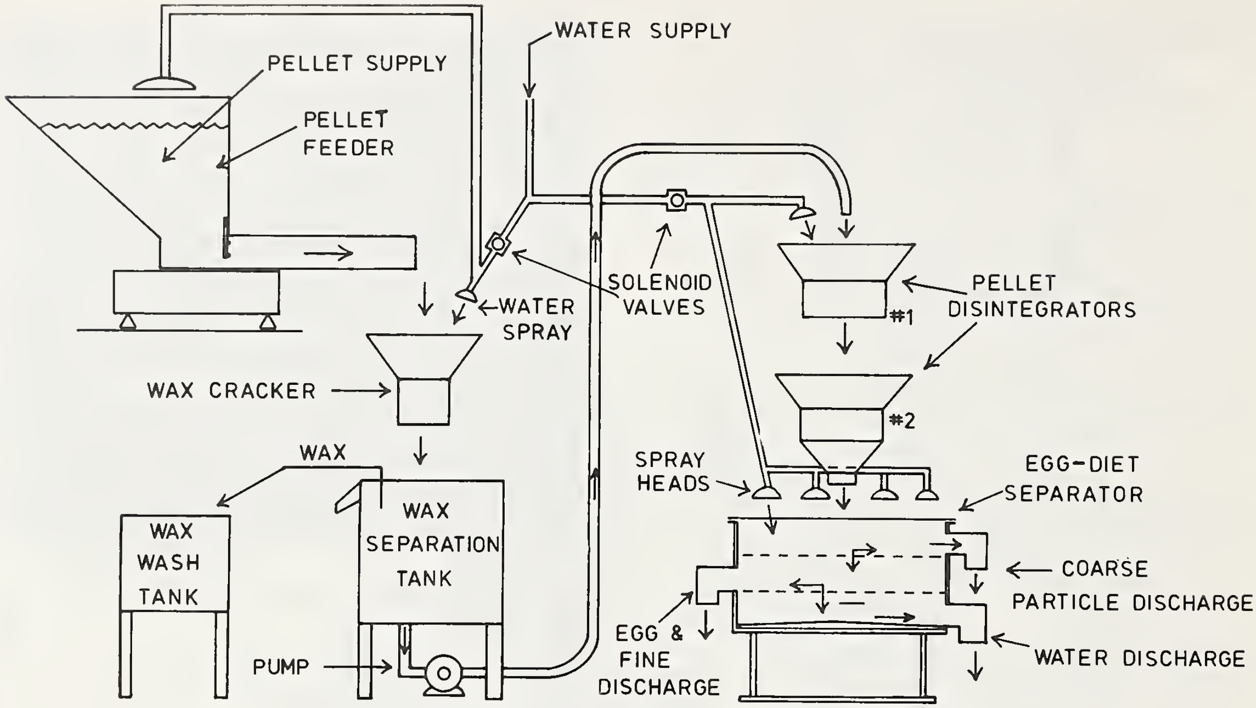


FIGURE 29.—Schematic diagram of equipment and materials flow in egg-extraction operation.

EGG-EXTRACTION AND WAX-RECOVERY AREA

This area should contain an egg-extraction room and a salt storage room or have a salt storage space conveniently located nearby. For efficient material flow, the area should be located near the brood-colony area. However, because of the wet and unsanitary conditions in the egg-extraction operation, there should be no direct opening between the two areas. The area should be heated and cooled for human comfort, and the egg-extraction room must have an air exhaust vented to the outside to remove the moisture produced in the operation.

The eggs are mechanically extracted from the pellets and cleaned (Griffin and Lindig, 1977, 1978; Griffin et al. 1979). A schematic of the material-flow and equipment layout for the egg-extraction operation is shown in figure 29. Egg-infested diet pellets are brought from the oviposition room, placed in the pellet-lift hopper, elevated by the lift, and dumped into the feeder hopper. Water is sprayed over the pellets as they leave the feeder. The pellets are discharged from the feeder into the wax-cracking unit, where they are fed between two fluted metal rollers that crack the wax coating on them. The two rollers rotate at speeds of 190 and 396 r/min; this difference in speed assists in cracking the wax coat and in feeding the pellets between the rollers. From the cracker, the pellet-water mixture is discharged into one compartment of a two-compartment tank, where it is agitated slowly with an air-operated mixer. Because of the damage that can be done by a fast rotating propeller, the mixer must not be operated at too high a speed. When the first compartment is filled, more mixture from the cracker is discharged into the second compartment of the tank to undergo the same procedure.

The mixer in the first compartment is stopped to allow the wax particles to float and the diet particles and eggs to settle. The wax is then removed from this compartment with a skimmer and placed in a container for washing and reusing. After the wax is removed, a transfer pump is turned on and the discharge valve of the compartment is opened. The pump, which must not damage the eggs, transfers the mixture to the first of two choppers, where more water is added from a spray head as the mixture passes through both choppers. (A pump used on food materials, soup, cottage cheese, etc.,

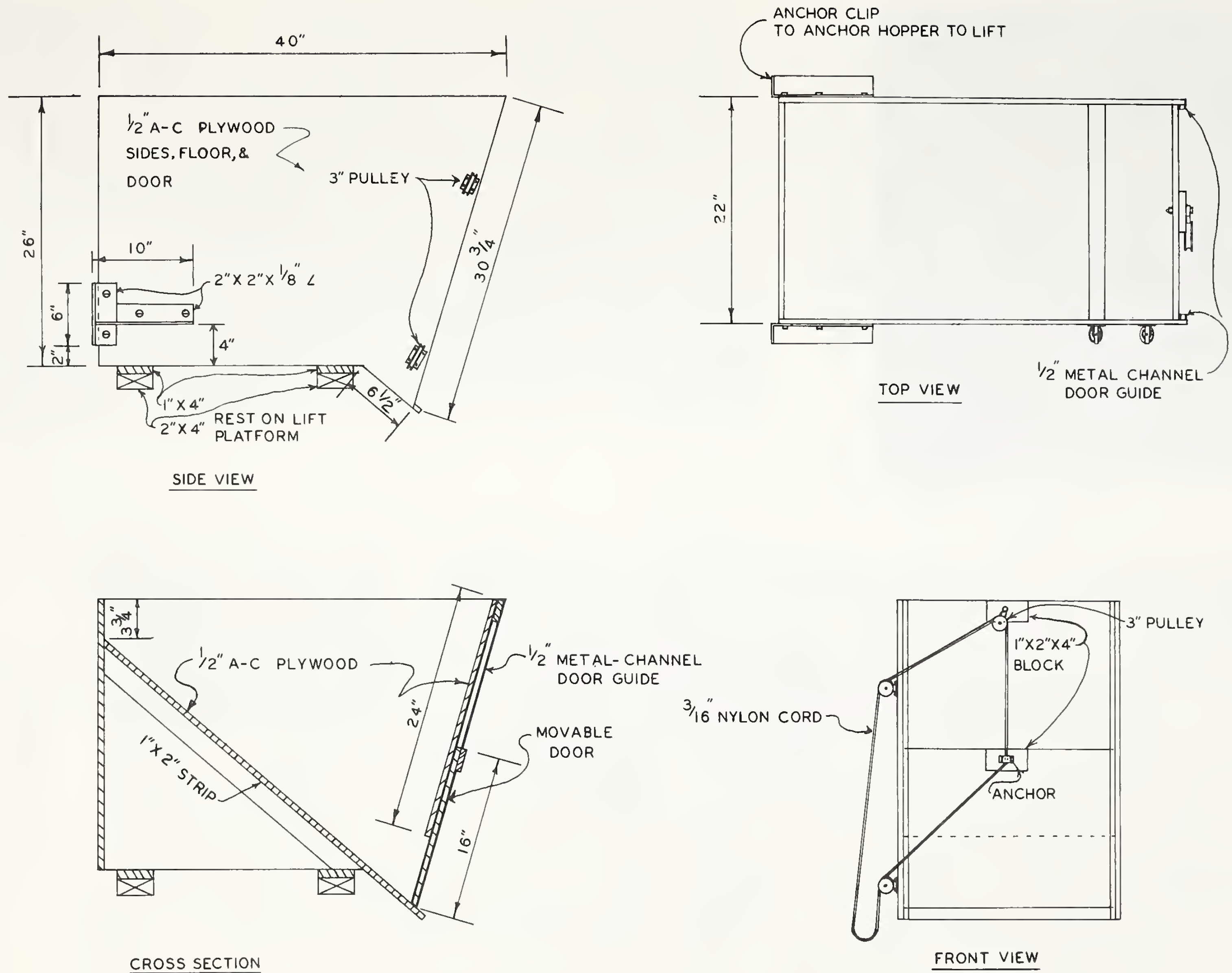


FIGURE 30.—Details of pellet hold-and-dump hopper.

was selected for this purpose.) The pellet particles are broken into smaller pieces by the choppers to expedite the release of the eggs. (Tests showed that using two choppers resulted in more eggs being collected and greater hatchability than when either chopper was used alone.) The blade shaft of each chopper turns at about 315 r/min. From the second chopper, the mixture is discharged onto the top deck of a two-screen-deck liquid-solid separator. The top deck removes all particles that will not pass through a 25-mesh screen, and the bottom deck removes all other particles that will not pass through a 50-mesh screen, including the eggs. The water and the remainder of the finer size particles are discharged from the liquid deck, and this mixture, plus the particles from the top deck, are discharged into a trough and delivered to the waste disposal system. The egg mixture is caught in a basket fabricated from 50-mesh screen that retains the solids but allows any water to drain from the basket. The eggs are separated from the diet particles with saturated NaCl brine in a 15-gal tank and finally with a 1,000-ml separatory funnel (Griffin and Lindig 1977, Griffin et al. 1979). The brine is prepared and stored in polyethylene tanks in the egg-extraction room.

Because of the operation of the water-spray heads and the washing of the equipment and floor, a high moisture level exists in the egg-extraction room much of the time. Therefore, caution must be taken to keep the stored salt dry. For this reason, the salt should be stored in a separate room or in another space nearby that can be kept free of excessive moisture.ure.

The wax recovered from the old pellets is washed and later boiled in a steam kettle to remove the water. This operation is performed in the egg-extraction room or may be done in an adjoining room. Because of the water and the possibility of diet particles getting on the floor of the egg-extraction room during operation, the floor surface must be made skid resistant or skidproof. Also, some wax particles are spilled on the floor and are washed down the drain when the floor is cleaned, so the drainage system should contain a wax (grease) trap that is easily accessible for removing the wax.

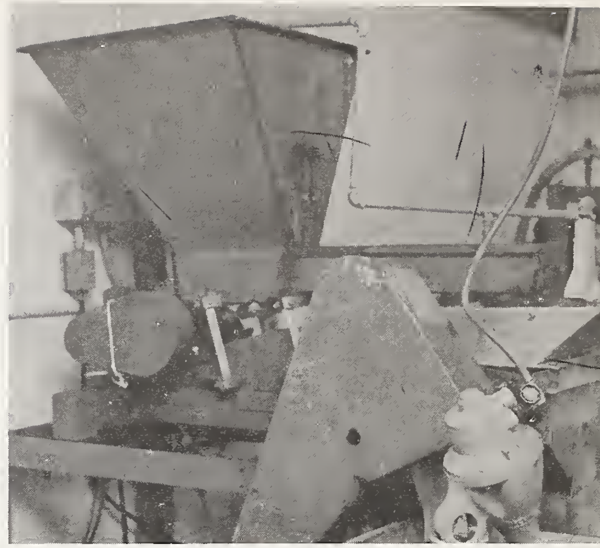


FIGURE 31.—Vibrator-feeder for feeding pellets into wax-cracking unit.

SPECIFICATIONS

A. Egg-extraction room
   1. Size, 16 ft wide, 16 ft long, and 10 ft high (minimum)
   2. Floor, concrete or similar material resistant to NaCl brine and nonslippery when wet; drain in floor with 4-in drain pipe (minimum); drainage system to contain grease or wax trap accessible for cleaning out loose wax and capable of handling waste diet material
   3. Walls, glazed-surface, masonry, resistant to brine solutions; ceiling made of water-resistant material
   4. Exhaust fan, moisture-resistant, vented to outside
   5. Duplex receptacles, weatherproof, wall-mounted about 10 ft apart, two per 20-A circuit; one special 3-phase, 60-Hz, 208- or 230-V, 20-A circuit for separator and two single-phase, 60-Hz, 208- or 230-V circuits for pumps and feeder motors; magnetic motor starters with pushbutton start-stop switches for each motor
   6. Ceiling-light fixtures, vaporproof, wall-switch controlled
   7. Double-compartment, stainless-steel sink, 24 by 21 by 14 in, and two 24- by 21-in drainboards, 14-gage metal (minimum), with sanitary rolled edges mounted on 1⅝-in (o.d.) stainless-steel tubular legs
   8. Cold-water supply line, 1 in (minimum), to room with cold-water outlet near pellet feeder, separator, and brine tanks; both

(*Continued on page 41.*)

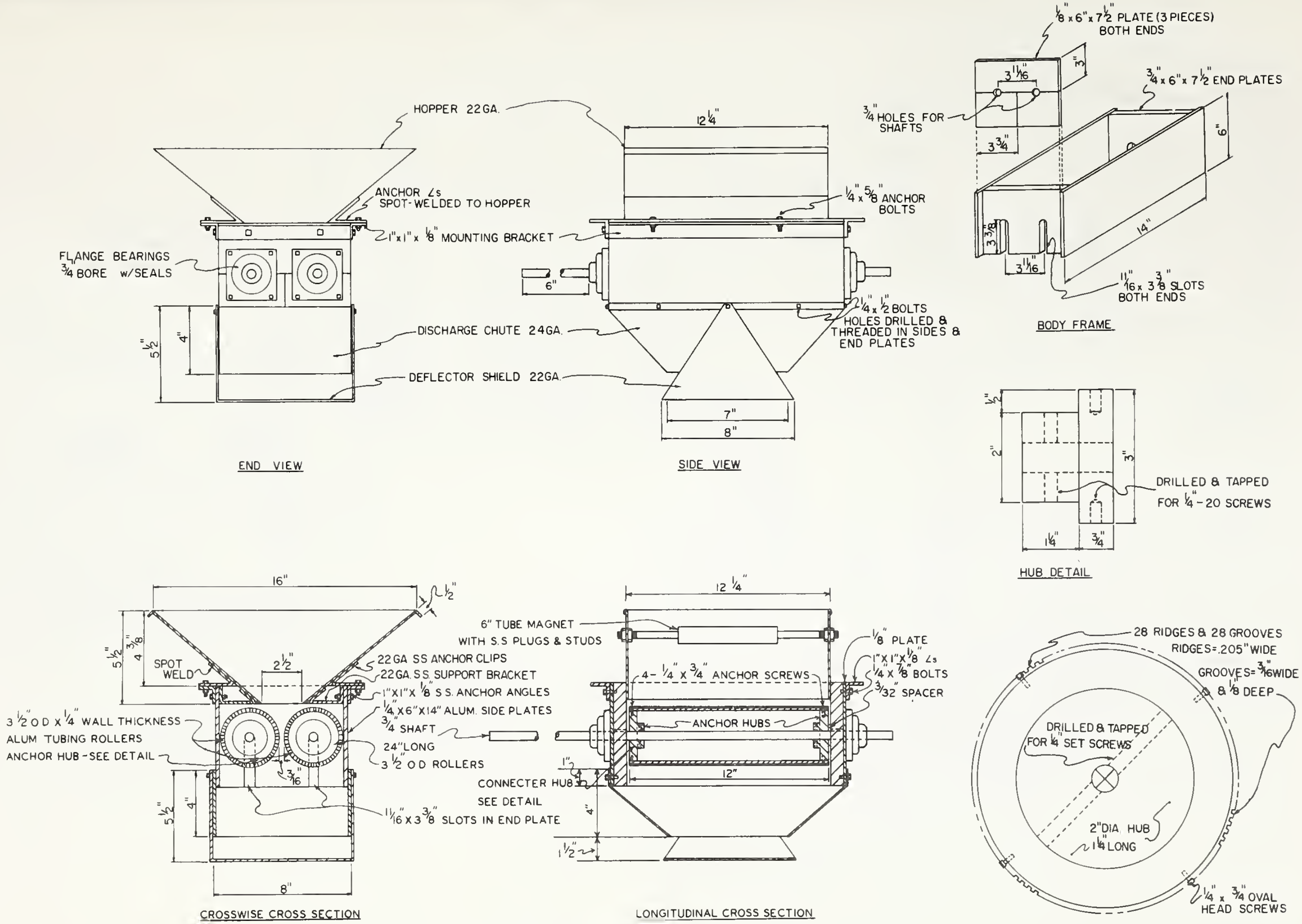


FIGURE 32.—Details of wax-cracking unit.

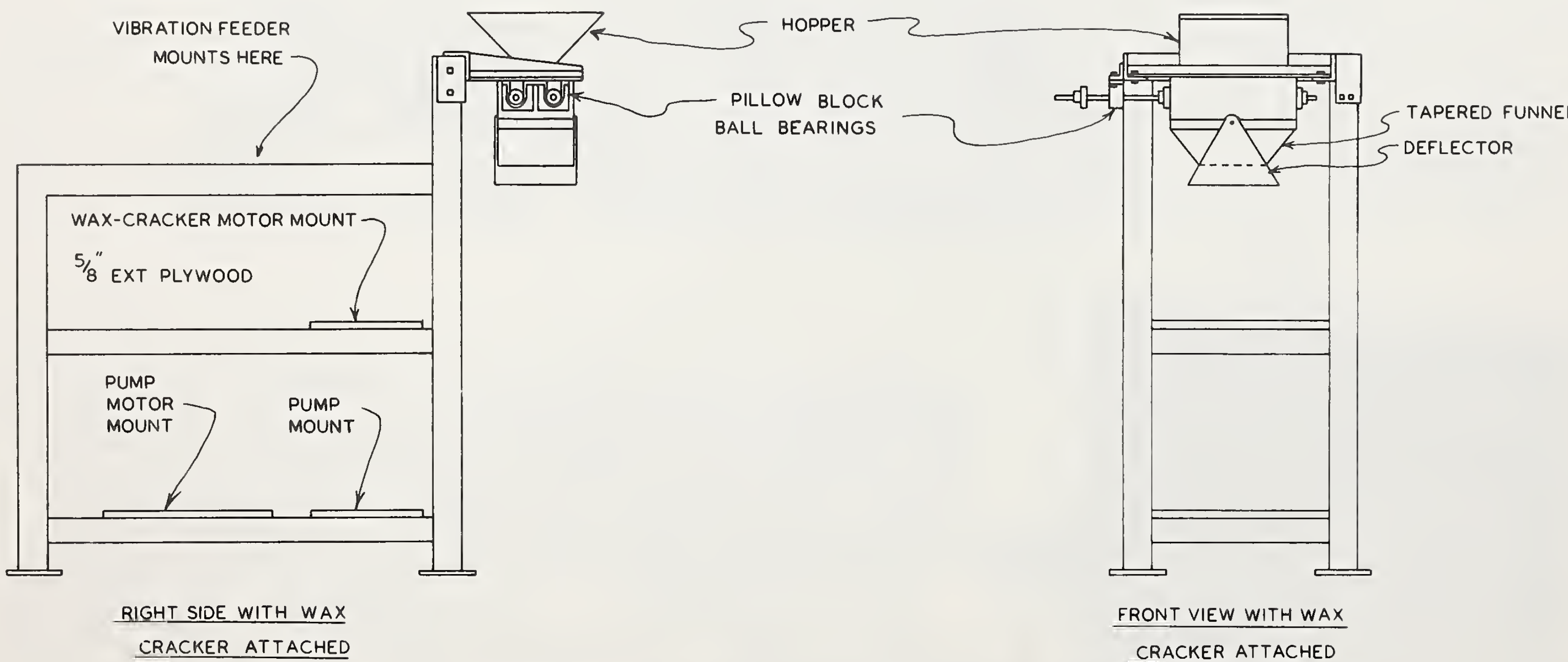


FIGURE 33.—Schematic diagram of wax-cracking-unit assembly.

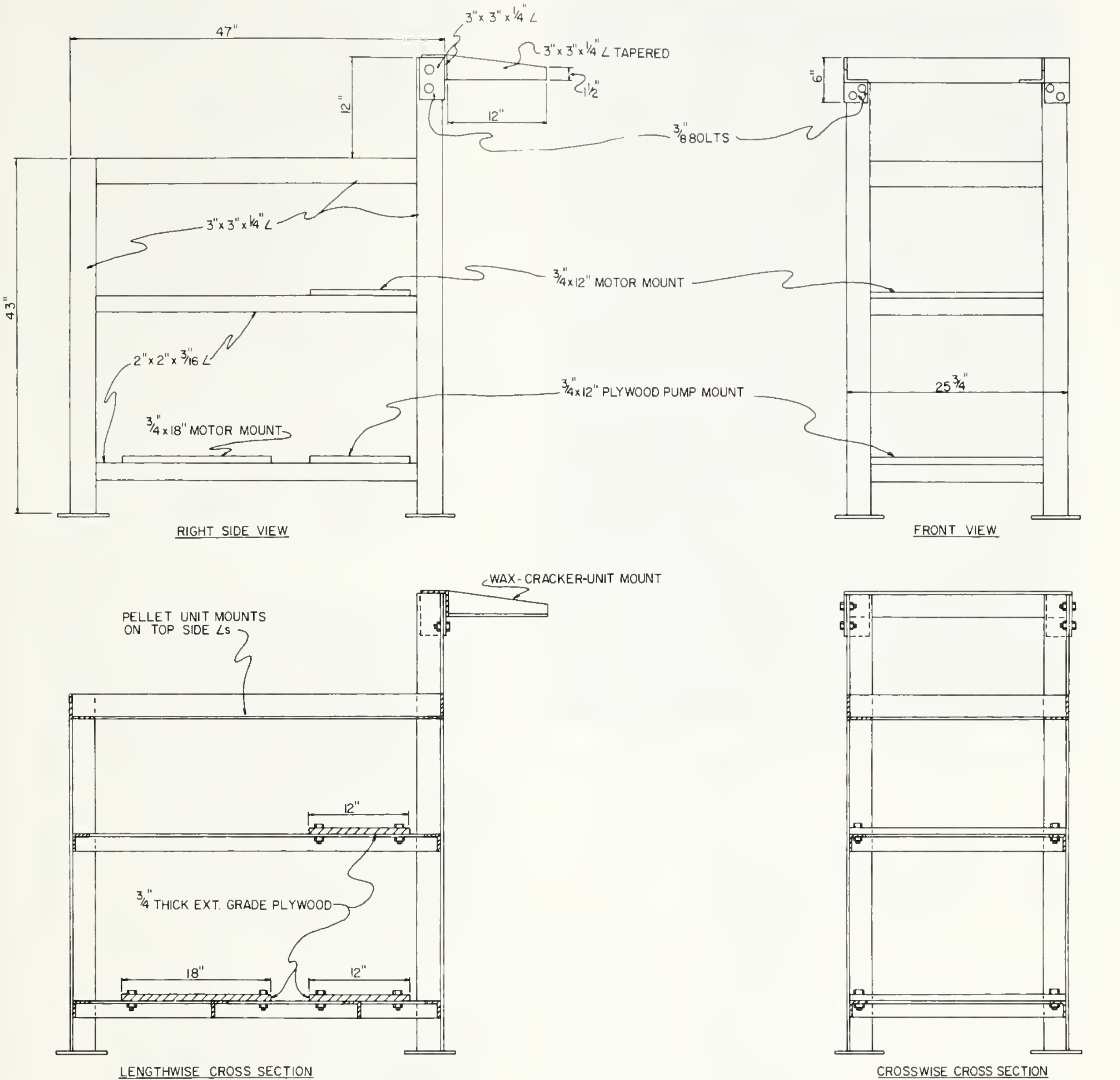


FIGURE 34.—Details of wax-cracking-unit frame.

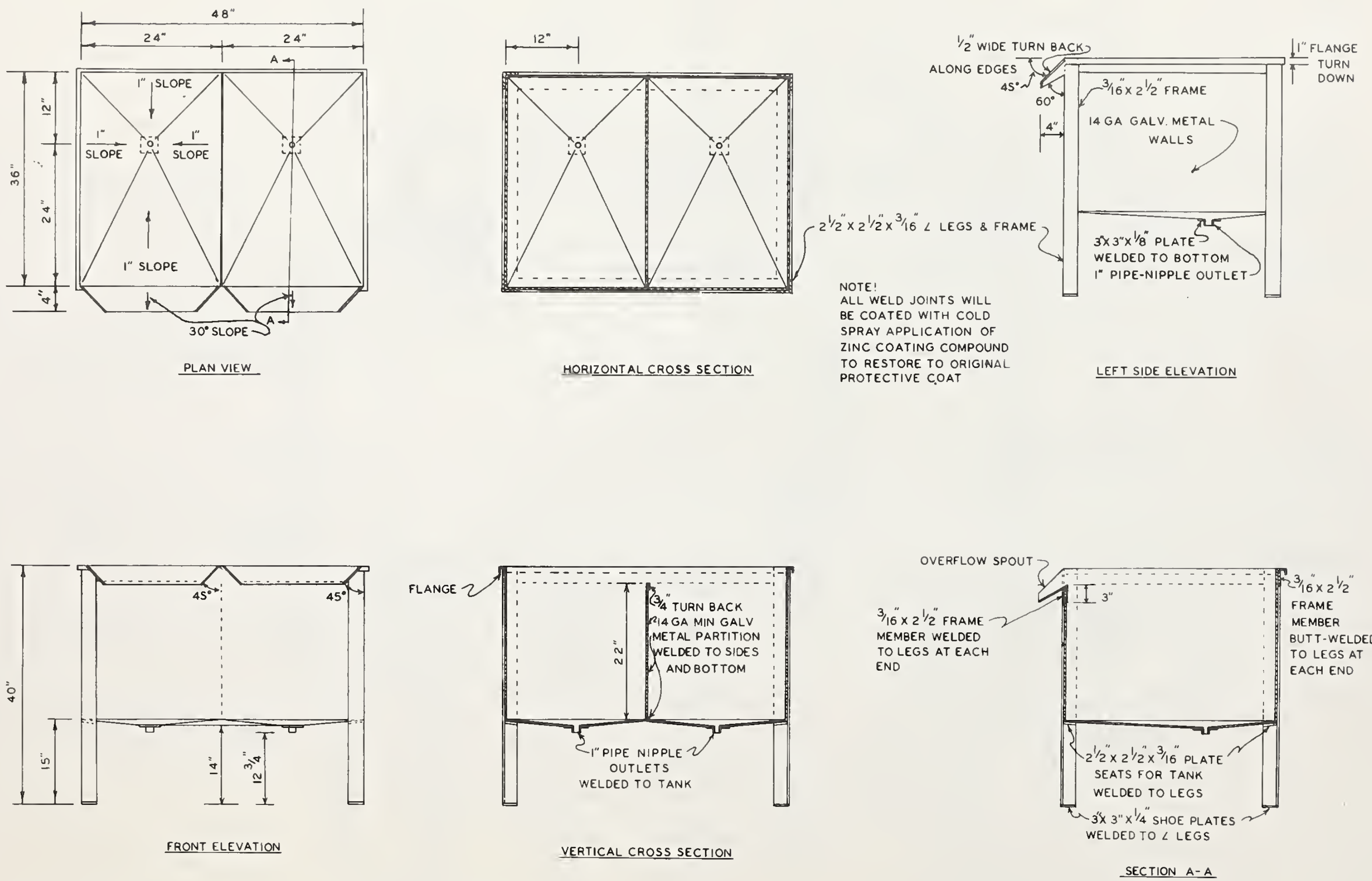


FIGURE 35.—Details of wax-separation tank.

cold- and hot-water sources at sink

9. Outlet for compressed-air supply, 60 lb/in^2 at 6 to 8 ft^3/min, located near wax-separation tank, for air motors on mixers
10. Convenient access to restroom and dressing room

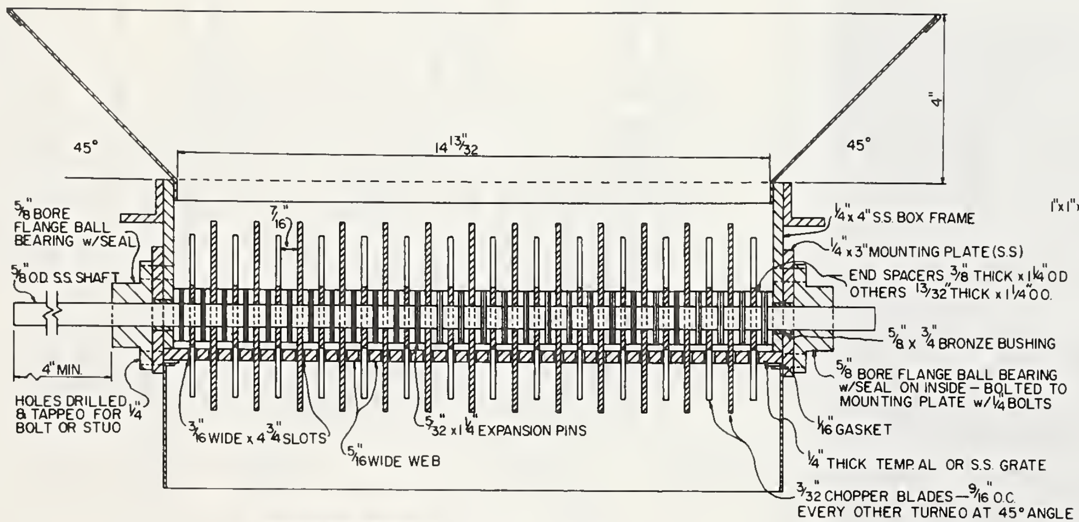
B. Salt storage room
  1. Salt usually procured in 100-lb paper bags; if stock available locally, large supply will not have to be stored
  2. Size, about 8 by 8 ft
  3. Floor, concrete, with slatted-wood overlay
  4. Walls, masonry, painted with epoxy enamel
  5. Located with door opening near egg-extraction room; if general-supply storage area is adjacent to egg extraction room, salt can be stored there
  6. Locate for conveniently getting bags of salt into storage area
  7. Ceiling light, wall-switch controlled
  8. Door, 3½ ft wide minimum

C. Equipment
  1. Pellet lift; unless laying colony is located above egg-extraction unit where old pellets can be fed by gravity through a chute into pellet feeder, pellets have to be collected and elevated to feeder hopper with the following equipment:
     (a) Hydraulic lift truck, Big Joe model 1518-R7 or equivalent, 1,500-lb lift capacity, 80-in lift height (minimum); operates on single phase, 60 Hz, 120 V; 26-in fork length (minimum); removable load platform to fit on forks; 5-in-diameter wheels (minimum)
     (b) Hold-and-dump hopper, constructed according to plans in figure 30; mounted on platform of lift and operated manually by cord and pulleys
  2. Pellet vibrator-feeder, ASEECO Corp. model VHF or equivalent (fig. 31)
     (a) Capacity of integral hopper, 4.5 ft^3 (minimum); trough, 6 in wide and 36 in long, with adjustable metering gate
     (b) Construction of hopper and tray, carbon steel, painted with FDA-approved, nontoxic paint
     (c) Vibration isolator, isocanes or air mount
     (d) Operates on single phase, 60 Hz, and 120, 208, or 230 V

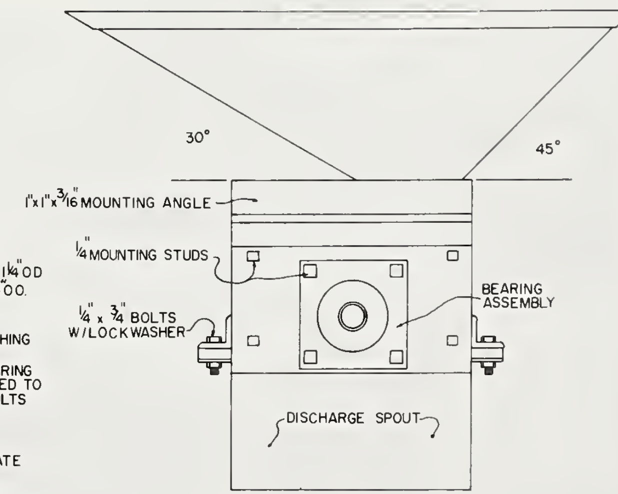
FIGURE 36.—Air-operated mixer used in wax-separation tank.

     (e) Water spray head installed over hopper to spray cold water on pellets being fed from hopper
  3. Wax-cracking unit (figs. 32 and 33)
     (a) Mounted on frame (fig. 34)
     (b) Water spray head installed over hopper to spray water on pellets
     (c) Waterflow to above spray head and to one over hopper of vibrator feeder controlled by solenoid valve operating on single phase, 60 Hz, 120 V; valve energized and deenergized by control switch to feeder motor
     (d) Driven by ⅓-hp, 157-r/min gearmotor with totally enclosed frame, Dayton model 2Z844 or equivalent
  4. Wax-separation tank (fig. 35)
     (a) Construction, 14-gage, galvanized-iron sheet metal
     (b) All welds on galvanized metal to be cleaned and recoated with cold solu-

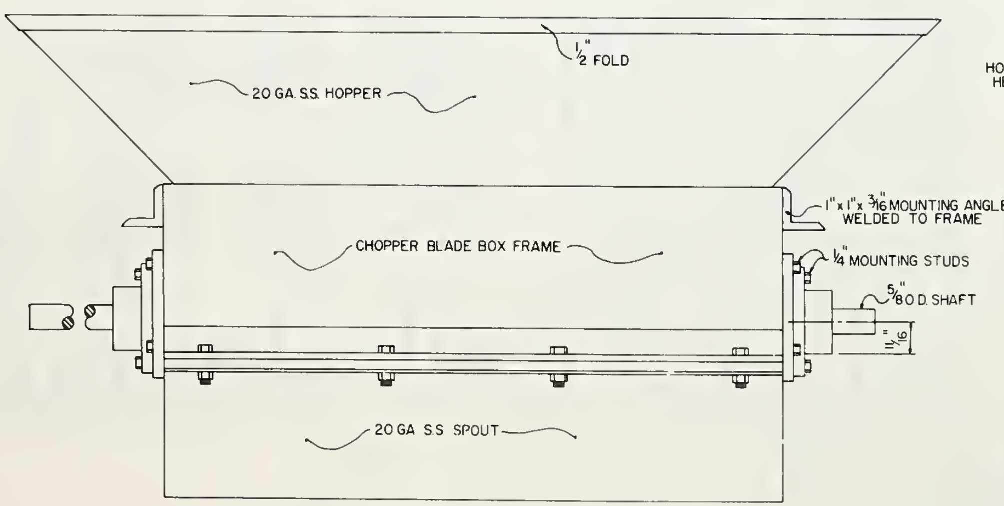
(*Continued on page 46.*)



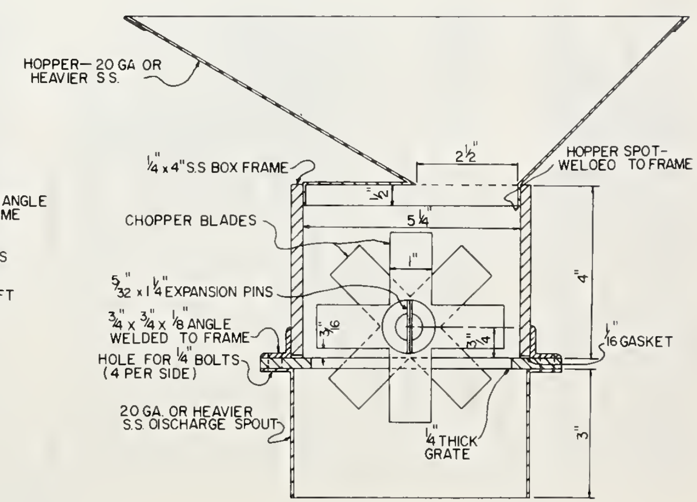
LONG CROSS SECTION THRU CENTER OF SHAFT



LEFT END ELEVATION



FRONT ELEVATION



CROSSWISE CROSS SECTION

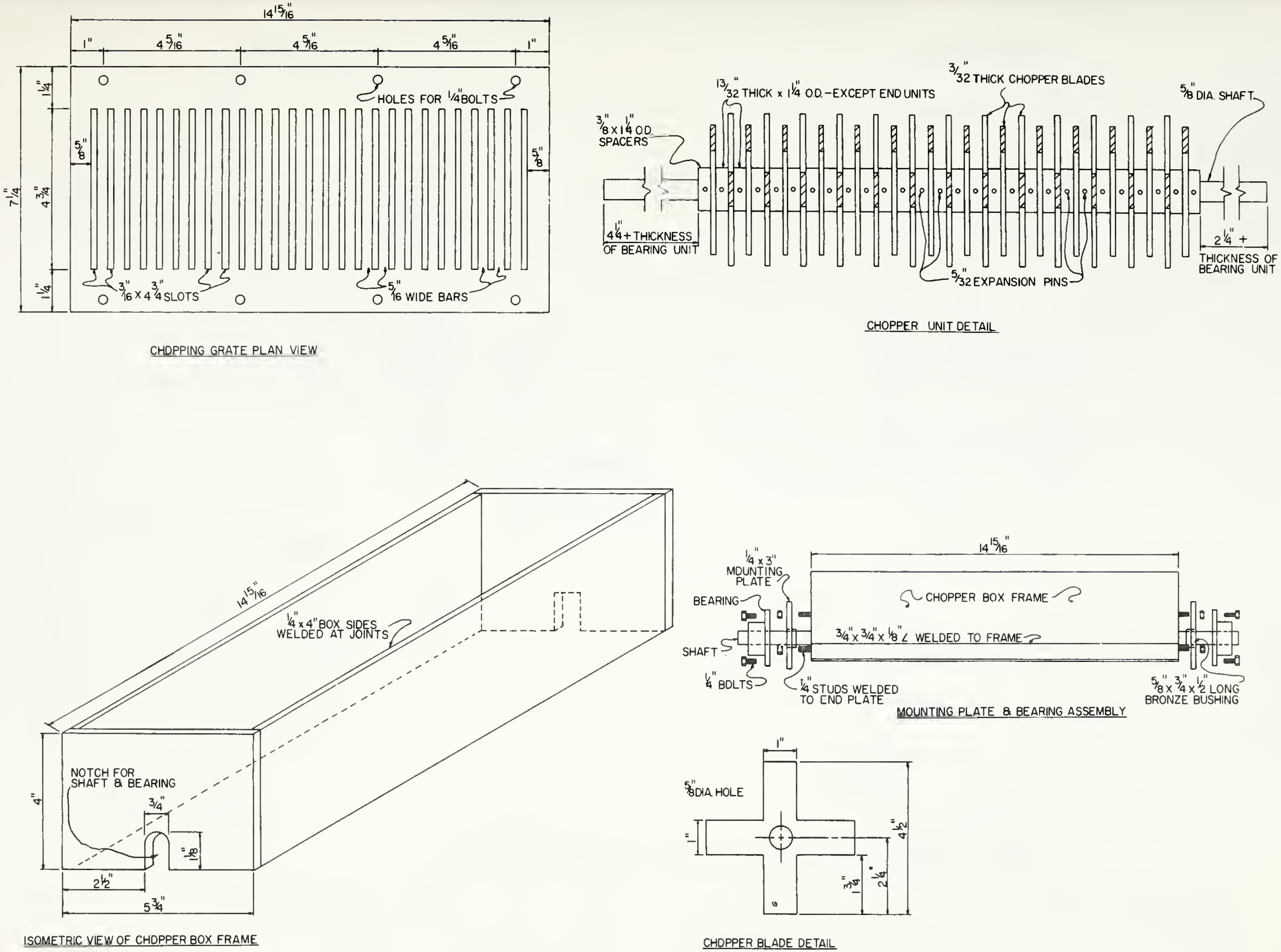


FIGURE 37.—Details of pellet-chopper unit.

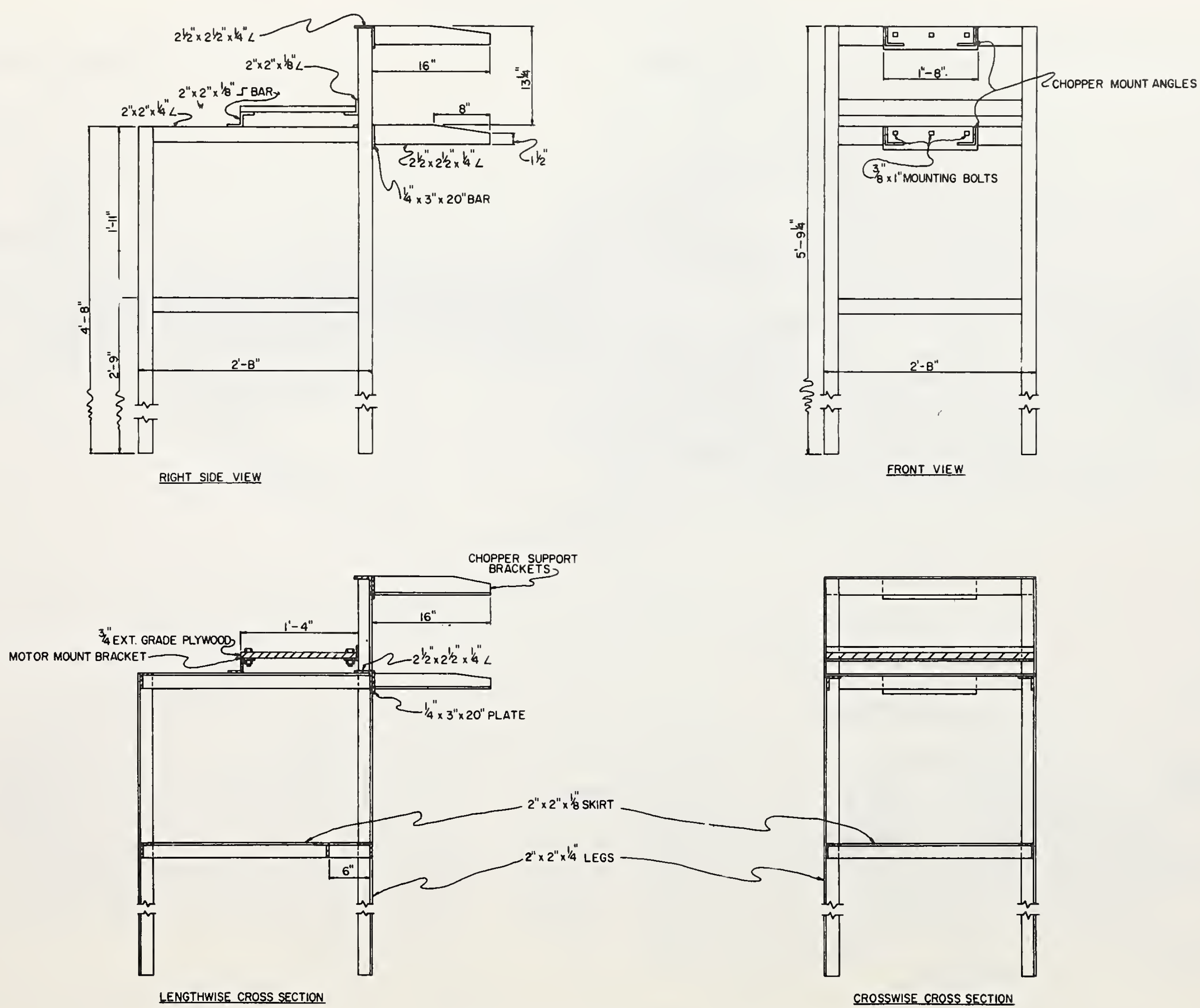


FIGURE 38.—Details of pellet-chopper mounting frame.

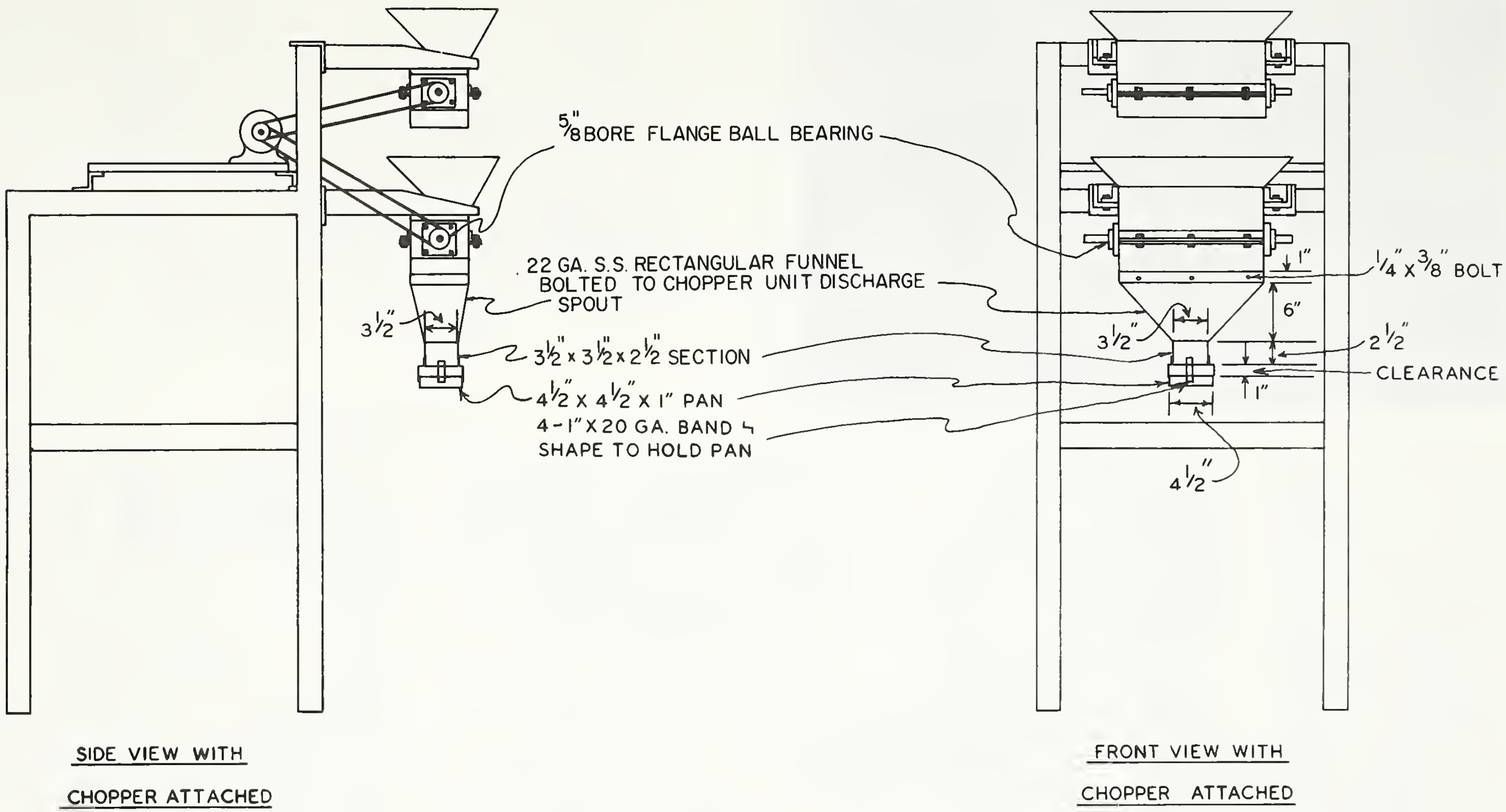


FIGURE 39.—Schematic diagram of pellet-chopper assembly.

tion of zinc
   (c) Partition between compartments to be welded to sidewalls and bottom to insure watertight joints
   (d) Air-operated mixer used in tank (fig. 36)
5. Pump, Waukesha model 10 WR, used to transfer egg-pellet-water mixture from separation tank to disintegrator (chopper) units
   (a) Sanitary-type, two-lobe impeller of Fibrerite plastic composition; pump body, corrosive-resistant nickel alloy; pump capacity, 10 gal/min at 20 lb/in^2
   (b) Motor, Dayton No. 6K119, adjustable-speed, capacitor-start, ½-hp, 1,725-r/min, single-phase, 60-Hz, 120-V, totally enclosed, with belt-and-pulley (two-groove) drive or torque-controlled sprocket with chain
6. Pellet chopper units (two each), used to reduce size of pellet particles in two stages (figs. 37-39)
   (a) Fan-shaped water spray head mounted over hopper of top chopper; waterflow controlled by solenoid valve energized and deenergized when pump and chopper motors turned on and off
   (b) Gearmotor, Dayton No. 2Z844 or equivalent, ⅓-hp, totally enclosed frame single-phase, 60-Hz, 120-V, 157-r/min; drives both chopper units
7. Liquid-solid separator, SWECO model LS30S666 or equivalent (fig. 40), used to separate as many diet particles as possible from eggs and to dewater eggs and remaining fine particles of diet left in mixture
   (a) Screened decks (two each), 30 in diameter; top deck 25-mesh and bottom deck 50-mesh stainless-steel hardware cloth
   (b) Discharge outlet, with flexible boot, located on each deck
   (c) Construction of deck frames, stainless steel
   (d) Variable adjustments for regulating proper feed-off of solid materials from surfaces of decks
   (e) Operates on single or 3 phase, 60 Hz, 208 or 230 V
8. Brine tanks, Nalgene model 1110-0080 or equivalent (three each), used to make and hold NaCl brine for removing fine-size particles of pellet material from eggs; must be made of brine-resistant material
   (a) Upright units, with capacity of 80 gal (minimum)
   (b) Construction polyethylene
   (c) Wall thickness, $^3/_{16}$ in (minimum)
   (d) Top rim rounded to increase strength and stiffness and thus prevent tearing or cracking
   (e) Stand, stainless-steel, constructed according to plans in figure 41; supports each tank
9. Egg-cleaning tank, United States Plastic Corp. No. 05199 or equivalent, used to mix brine with egg mixture for initial egg-cleaning operation
   (a) Unit round and upright, with dome-shaped bottom; capacity, 15 gal
   (b) Outlet, ¾ in, installed in bottom for drainage; flexible rubber hose attached to outlet with hook attached at other end
   (c) Metal stand, United States Plastic

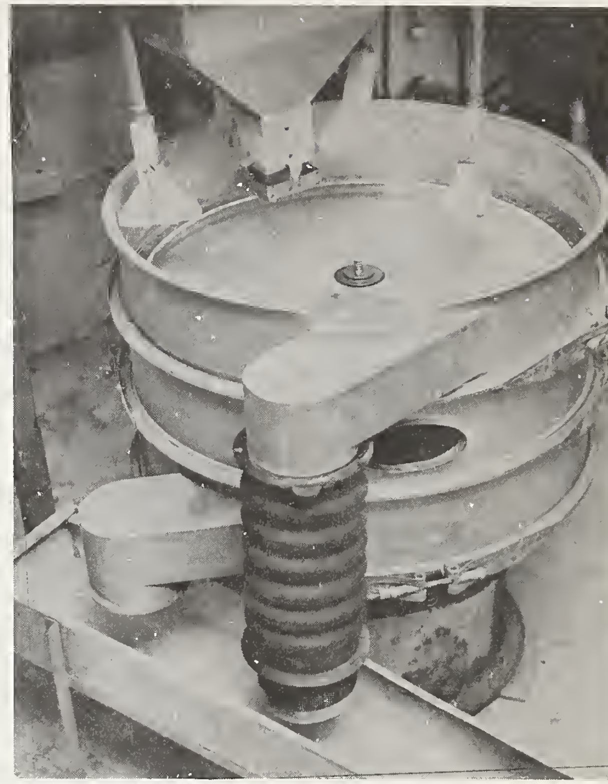


FIGURE 40.—Liquid-solid separator for egg harvesting.

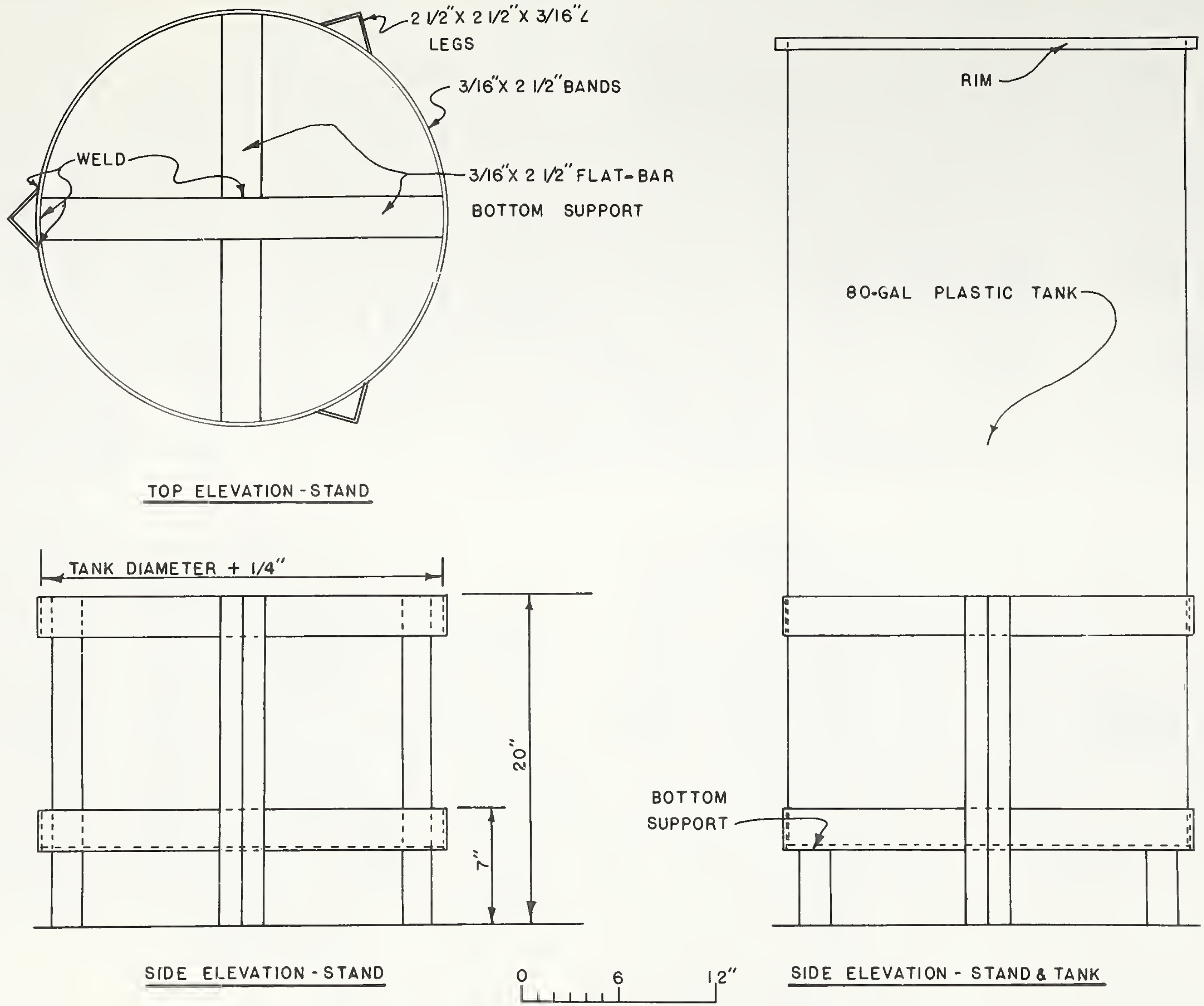


FIGURE 41.—Details of brine-tank stand.

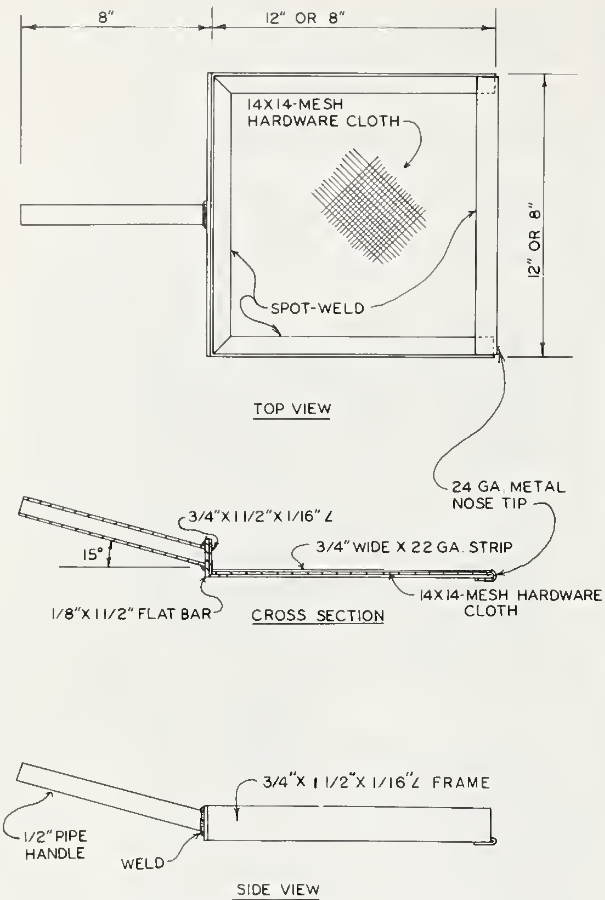


FIGURE 42.—Details of wax skimmer.

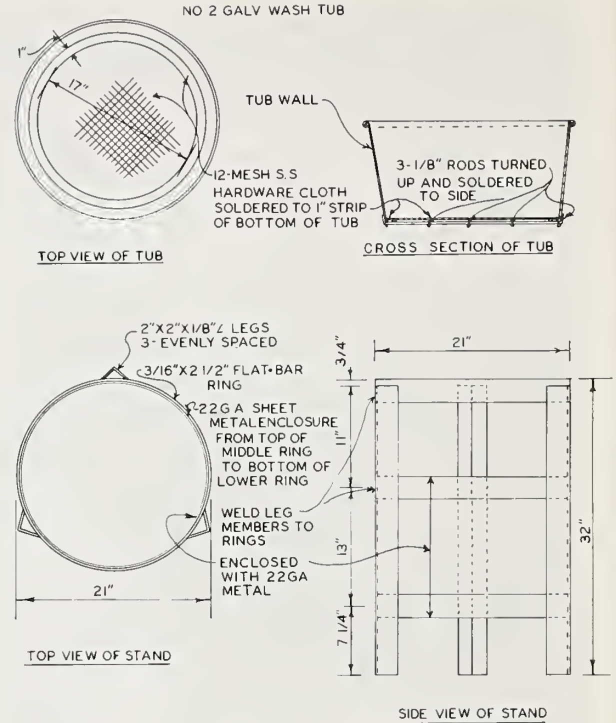


FIGURE 43.—Details of washtub and stand.

Corp. No. 05060 or equivalent; supports tank

10. Wax skimmer and washtub; skimmer used for removing or recovering wax from separation tank, washtub used for washing and draining wax after its removal from tank and just before melting for recycling
    (a) Skimmers (two each), constructed of stainless steel according to plans in figure 42
    (b) Washtub, regular No. 2 galvanized, with all but 1-in rim of bottom cut out and piece of 14-mesh hardware cloth installed and soldered to rim; washtub prepared and stand constructed according to plans in figure 43
11. Steam kettle, Legion Equipment Co., Inc. or equivalent, used to boil water from wax collected in egg-extraction operation
    (a) Tank, 80-gal capacity; two-thirds jacketed, 18-8 composition, type 304 stainless steel
    (b) Tangent-type drawoff line with compression disk-type drain valve
    (c) Operates on 40-lb/in^2 steam pressure
    (d) Construction to meet all ASTM codes
    (e) Legs, tubular-steam, enameled
    (f) Accessories include popoff safety relief valve, steam-pressure regulator (0 to 25 lb/in^2), and steam trap

EGG- AND SOLUTION-PREPARATION AREA

This area is used to surface sterilize (Sikorowski et al. 1977) eggs and prepare the equipment and solution for placing the eggs on the diet (Gast 1966, Griffin et al. 1979). All work can be done in one room, but microbial contamination must be maintained at a low level. The conditioned air supply should be filtered by HEPA filters. There should be no direct passageway into other areas of the facility, and entrances should be through

interior or exterior halls or walkways. Materials should be passed to other areas through airlock, passthrough cabinets to maintain sanitation and efficiency. The floor and walls must withstand washing and spraying with Clorox or similar disinfecting solution (Sikorowski 1975).

SPECIFICATIONS

A. Room
   1. Size, about 16 by 24 ft
   2. Floor, concrete, covered with broken quarry tile; toeboard, drain, and cap
   3. Walls, masonry, painted with epoxy enamel
   4. Air-conditioning air supply into room through HEPA filter
   5. Two-compartment sink, 24 by 21 by 14 in, with drainboards; fume hood vented through roof and located over sink; switch-controlled fan
   6. Recessed ceiling lights, wall-switch controlled
   7. Duplex receptacles, weatherproof, wall-mounted about 8 ft apart, maximum three per 20-A circuit
   8. Entrance door, 3½ by 7 ft (minimum)

B. Clean-air laminar-flow work station
   1. Worktable surface, about 24 by 72 in; console model constructed of stainless steel or laminated plastic to withstand cleaning with Clorox
   2. Light fixtures mounted to work surface
   3. Filters, HEPA, with efficiency of 99.97% for dust particles 0.3 μm and larger
   4. Air velocity in front of filters, 110 ft/min (minimum)
   5. Air volume adjustment
   6. Laminar-flow hood, Liberty Industries, Inc. 4-410 M series or equivalent

C. Equipment
   1. Autoclave, American Sterilizer Co. model or equivalent, used for sterilizing bottles, caps, and planting solution
      (a) Size, 20 by 20 by 38 in
      (b) Laboratory type with stainless-steel cabinet panels, single-door model
      (c) Condenser exhaust
      (d) Shelves (two each), full-length, removable, monel
      (e) Meets ASME Boiler and Pressure Vessel Code and be so stamped
      (f) Use saturated steam as sterilizing agent
      (g) Operates on auxiliary steam source
      (h) Manual controls
   2. Laboratory Shaker, Eberbach model or equivalent
      (a) Shaker carrier with capacity of two 4,000-ml jars
      (b) Cross rod to secure jars in carrier
      (c) Base with motor to operate on single phase, 60 Hz, 120 V
   3. Bottles (18 each, minimum), 3 to 4 l, autoclaveable-glass, with vacuum-seal rubber caps

GRANULAR-MATERIAL STORAGE AREA

A mixture of sterile, sifted mortar (mason) sand and corncob grits is used to cover the eggs and larval diet in the rearing trays (Griffin 1978, Griffin and Lindig 1975, Griffin et al. 1979). The corncob grits can be stored in the general-supply storage area, but the sand should be stored in a covered bin conveniently located outside the rearing building.

SPECIFICATIONS

A. Sand bin
   1. Size determined by availability of sand locally and capacity of delivery truck; storage capacity, 8 yd^3 (minimum), 18 yd^3 (maximum)
   2. Floor, reinforced concrete
   3. Walls, reinforced concrete or masonry on three sides, with one side open and floor sloping to open side
   4. Removable or foldup cover for bin
   5. Unit located near drying pad or drying equipment

B. Corncob grits storage area, allow 32 ft^2 of floor space in general-supply storage area; material must be kept dry

GRANULAR-MATERIAL PREPARATION AREA

A sterile mixture of sand and corncob grits is spread in the trays over the larval diet and eggs. The sand is dried, sifted, weighed on scales in batch-size lots, and sterilized in an

autoclave. The corncob grits are also weighed in batch-size lots and sterilized. These two sterilized materials, plus the correct amount of antimicrobial agents, are blended to a homogenous mixture that is then stored in sterilized containers.

To conserve energy, the sand can be spread in the sun on a concrete or asphalt blacktop pad for drying and then swept up and placed in a dry-sand storage bin, or it can be dried in a heated air-dryer unit or cabinet.

Two separate inside spaces or rooms are needed for preparing these materials. One room is used to process the sand through sterilization, while the other room is used to prepare the material for use in the trays. These two rooms should be connected by an airlock passthrough for the materials only. There are no connecting passageways for personnel. For efficiency and cleanliness, a passthrough should connect the rooms with the rearing-tray processing area.

FIGURE 44.—Sand-dryer cabinet for heated-air drying.

SPECIFICATIONS

A. Room 1
   1. Size, 12 by 24 by 8 ft
   2. Floor, concrete with drain
   3. Walls, masonry
   4. Ceiling, ¼-in tempered masonite, painted with epoxy enamel
   5. Ceiling light, wall-switch controlled
   6. Duplex wall receptacles, weatherproof, not more than 12 ft apart, two per 20-A circuit
   7. Special 3-phase, 60-Hz, 208- or 230-V, 40-A circuit for sand-drying oven
   8. Source of 30-lb/in^2 steam pressure for autoclave
   9. Cold-water line for autoclave condenser
   10. Entrance door, 4 by 7 ft, conveniently located to sand and corncob grits storages
   11. Double-door passthrough between rooms 1 and 2
       (a) Size, 36 in wide, 30 in high, and 32 in long, with 28- by 24-in doors
       (b) Construction, ¾-in, waterproof, exterior-grade plywood, painted with epoxy enamel
       (c) Removable shelf flush with bottom of door opening

B. Room 2
   1. Size, 12 by 12 by 8 ft
   2. Floor, concrete, with broken quarry-tile covering or equivalent
   3. Walls, masonry, painted with epoxy enamel
   4. Ceiling, gypsum-board, painted with epoxy enamel
   5. Ceiling light, wall-switch controlled
   6. Duplex wall receptacles, weatherproof, not more than 12 ft apart, two per 20-A circuit
   7. Special single-phase, 60-Hz, 208- or 230-V circuits for blowers in laminar-flow cubicles
   8. Entrance door, 3½ by 7 ft, for equipment passage
   9. Double-door passthrough to rearing-tray processing area (same as between rooms 1 and 2)

C. Equipment
   1. Sand dryers; for solar drying, a pad (about 600 ft^2) of concrete or blacktop that will receive full sunlight during the entire day; for heated-air drying, either a continuous-flow dryer system or a heated cabinet, Hotpack Corp. model 214300 or equivalent (fig. 44), which is less

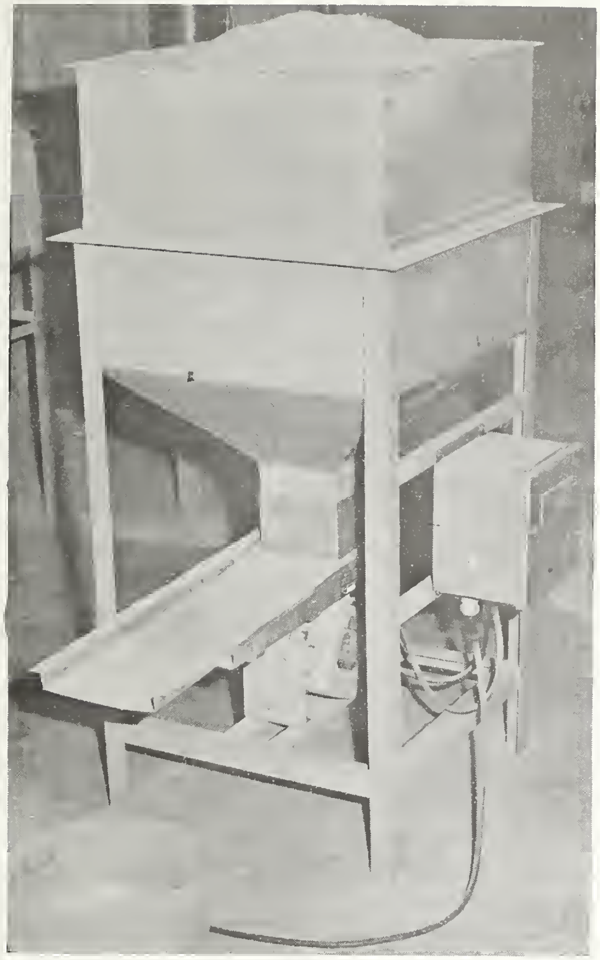


FIGURE 45.—Vibrating sand sifter.

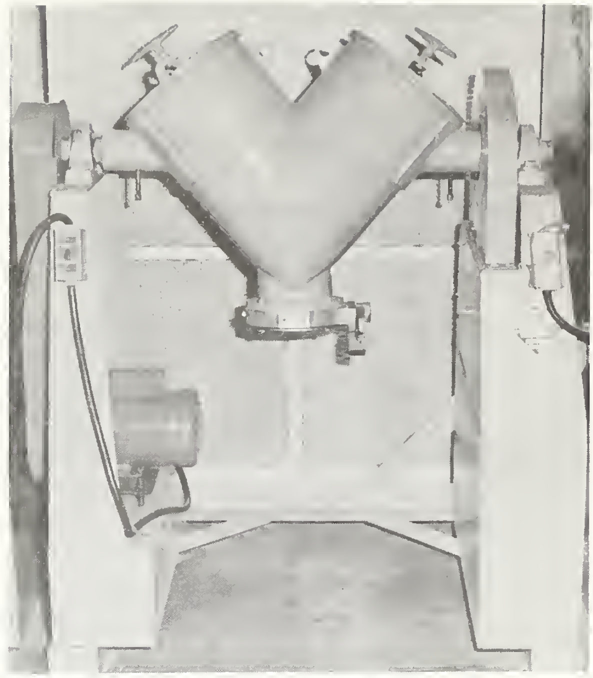


FIGURE 46.—Twin-shell blender for mixing granular materials and antimicrobial agents.

expensive for this size operation and is therefore recommended
   (a) Heating capacity, 8.5 kW (minimum), with forced-air circulation
   (b) Inside dimensions, 36 by 36 by 72 in (minimum)
   (c) Temperature indicator and control on outside
   (d) Provisions to adjust air exhaust and intake
2. Autoclave, used to sterilize sand and corncob grits
   (a) Size, 24 by 36 by 60 in (minimum), general purpose
   (b) Condenser exhaust
   (c) Single door, manually operated
   (d) Cabinet panel, stainless-steel
   (e) Meets all ASME codes
   (f) Maintains jacket and cabinet temperatures separately
   (g) Necessary pressure regulators, steam traps, gages, and other accessories for operation
3. Sand sifter, Eriez Magnetics model or equivalent
   (a) Vibratory unit with 6-in-wide trough and 16- by 16-mesh hardware-cloth sieve or screening tray (fig. 45)
   (b) Hopper capacity, 3 ft^3 (minimum)
   (c) Screening tray to extend minimum of 6 in beyond trough
   (d) Mounted on stand to give 16-in clearance (minimum) between floor and trough
   (e) Vibratory bin vibrator
   (f) Dual vibrator control, one for bin and one for feeder
   (g) Operates on single phase, 60 Hz, 120 V
4. Balances, used to weigh and proportion sand, corncob grits, and antibiotics
   (a) No. 1 unit, Mettler model E20N or equivalent
      (1) Top-loading; capacity, 20 kg
      (2) Operates on single phase, 60 Hz, 120 V
   (b) No. 2 unit, Mettler model P2N or

equivalent
  (1) Top-loading; capacity, 2 kg
  (2) Operates on single phase, 60 Hz, 120 V

5. Blender, Patterson-Kelly model or equivalent (fig. 46)
   (a) Working capacity, 1 ft^3
   (b) Twin-shell type with intensifier bar
   (c) Contact material made of stainless steel
   (d) Operates on single phase, 60 Hz, 120 V
   (e) Separate switch for motors of intensifier bar and main shell
6. Clean-air laminar-flow cubicle, used to provide clean air across work area when granular materials are being placed in and removed from blender and placed in storage containers
   (a) Should be 6 ft wide and 6 ft high, with sidewalls and ceiling extending at least 6 ft from filter modules
   (b) HEPA filters with 99.97% efficiency for particle sizes 0.3 μm and larger
   (c) Fans to deliver air at minimum velocity of 110 ft/min over surface area of filters

PLASTIC AND COVER STORAGE AREA

Roll stock of high-impact polystyrene and Tyvek (Du Pont Co.) or kraft paper is used to form and cover the rearing trays, respectively (Griffin 1978, Harrell et al. 1977, Harrell et al. in press). The polystyrene, purchased by the pound in about 60-lb (20- to 21-in-diameter) rolls, should have a uniform thickness of about 17 mil. Tyvek is a woven plastic that allows an air-water exchange and is coated with a heat-sealing adhesive that will adhere to the high-impact polystyrene. It is purchased by the linear foot in 1,000-ft rolls or a convenient size to fit the forming machine. Both materials should be purchased in large quantities because of the cost savings and the delivery time involved; thus, the storage area should be adequate to stock a minimum 6-week supply when at full operation. A conveniently located 4-ft-wide doorway is required for bringing the materials into the storage area. The materials must be kept clean and be fumigated with formaldehyde gas before use; therefore, a passthrough fumigation chamber should connect this storage area with the rearing-tray processing area for efficiency in materials flow. To prevent contamination, there should be no direct passageway for personnel between the storage and rearing-tray processing areas.

SPECIFICATIONS

A. Storage room
   1. Size, 12 by 12 ft (minimum), excluding area for fumigating chamber
   2. Floor, concrete, reinforced to withstand load of materials; quarry-tile cover optional
   3. Ceiling light, wall-switch controlled
   4. Walls, masonry, painted with epoxy enamel
   5. Duplex receptacle, weatherproof, located in each wall; single-phase, 60-Hz, 120-V
   6. Air conditioned for human comfort, but air should not be circulated from any of less-clean rooms into this room
   7. Doorway, 4 by 7 ft, for material entrance; windows optional but if used should be stationary glass panels
B. Fumigation chamber
   1. Size, 2 by 4 by 4 ft (fig. 47)
   2. Construction, ¾-in plywood, with all joints sealed tightly
   3. Passthrough unit with door on both sides
   4. Painted inside and outside with epoxy enamel
   5. Installed on wall between storage area and rearing-tray processing area so that it protrudes into latter area just enough to place trim strip around unit to cover and seal any cracks left in wall opening
   6. Support legs, 1½-in pipe, installed at the two protruding corners in storage room
   7. Hinges and latch, 1⅛-in, offset-style

REARING-TRAY PROCESSING AREA

This area should not have a direct passageway to any other area of the rearing facility (fig. 48). Passage into the larval-development area should be through a walkthrough airlock cubicle. This area should have a separate air-conditioning unit. Supply air from the air-conditioning system should enter the room through HEPA filters, and recirculated air from any other area should not be allowed to enter. To minimize the length of the sterile larval-diet transfer line, the rearing-tray processing area should be located adjacent to the

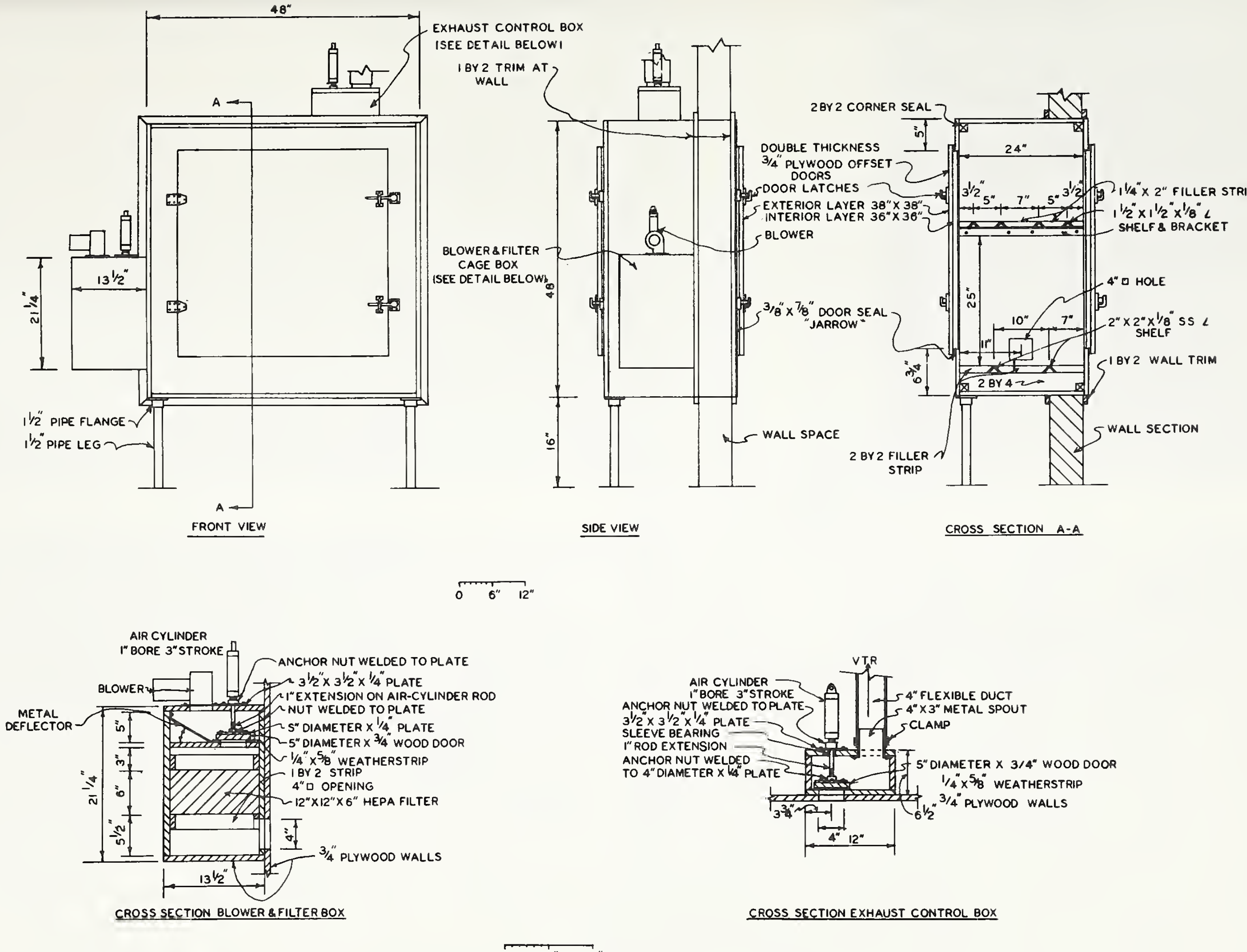


FIGURE 47.—Details of fumigation chamber.

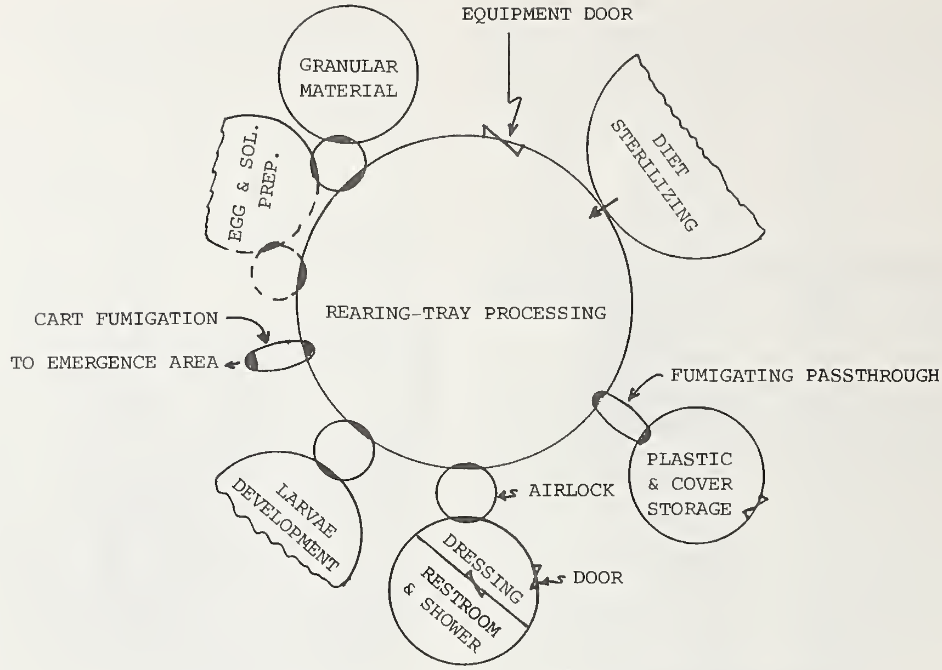


FIGURE 48.—Arrangement of rooms in rearing-tray processing area.

diet-sterilization area. An airtight transparent glass or plastic panel between these two areas is very desirable.

Cleanliness must be a major objective in the design of the rearing-tray processing area, including the air, floors, walls, and equipment. The floors and walls are washed down and sanitized daily (Sikorowski 1975). A laminar-flow room provides the best air cleaning, i.e., airflow in which the entire body of HEPA-filtered air within a confined area moves with uniform velocity along parallel flow lines. The air in this area should attain a Class 100 condition ($\leq$ particles larger than 0.5 μm/ft^3).

Pathologically, a true vertical laminar-flow room would most likely be unacceptable because of the perforated floor requirements; therefore, a version of the laminar-flow room must be provided. Either a vertical or horizontal airflow room could be used satisfactorily; however, the vertical airflow room has a slight cleanliness advantage. A curtain-type vertical laminar-flow room (portable) may be used satisfactorily when placed over the forming machine. This unit will maintain a Class 100 condition with an air velocity of 90 ± 10 ft/min (Lindell et al. 1969); however, the work surfaces must be maintained 18 in or more above the floor.

The rearing-tray processing room must accommodate a form-fill-seal machine, a diet dispenser, a diet cooler (two compressor-condenser units located near but outside the room), an egg-planting unit, a granular-material dispenser, three or four rackveyor units, a double-compartment sink, and a cabinet (about 2 by 3 by 6 ft) for tools and extra parts. Space is also required for loading the tray rackveyor. Part of the plastic and cover fumigation chamber, the granular-material passthrough cabinet, and the rackveyor fumigation chamber could extend into the room, but preferably these would be in adjoining rooms with openings only into this room.

After being washed, all rackveyors used each day (four) are fumigated simultaneously with formaldehyde gas before being reused. The chamber must be large enough to accommodate all four units and be gasproof, with provisions to exhaust the gas and flush the chamber with clean fresh air before opening the door. The exhaust system must be vented through the roof, and the fresh-air intake must be filtered. Ideally, the chamber should have two doors, one with access to a hall or walkway from the cleanup room of the emergence area and the other opening into the rearing-tray processing room or into an airlock cubicle between the rearing-tray processing room

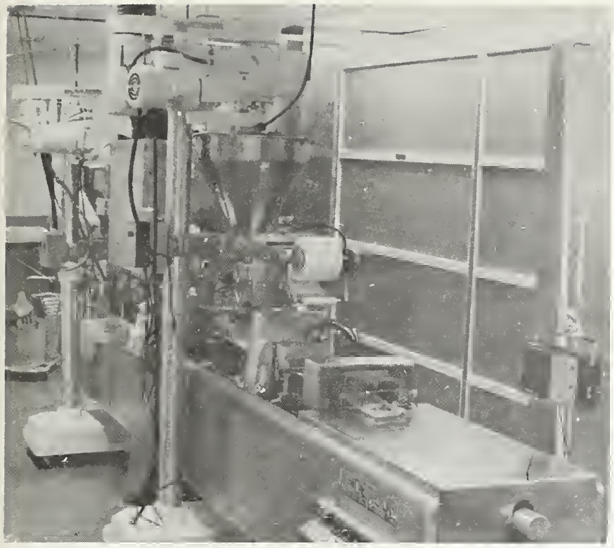


FIGURE 49.—Formseal machine with auxiliary equipment for mass rearing of boll weevils.

and the No. 1 larvae development room, preferably the latter.

All material coming into the rearing-tray processing room should be sanitized or sterilized. Consideration should be given to showers, footbaths, and laboratory garments, including those for the head and feet, to be changed into after personnel enter the room from the street.

An inline form-fill-seal machine, Anderson Brothers Formseal model 655BS, has been modified (fig. 49) and successfully used in the rearing system discussed in this publication (Griffin 1978, Harrell et al. 1977, Sparks and Harrell 1976). It has been production-tested for rearing 6¼ million boll weevils per week over an 8-week period. This machine was designed for plastic 6 to 6½ in wide and has dies that form trays about 4½ by 10⅕ by ¾ in deep. Roll stock, high-impact polystyrene 6 in wide and 15 to 17 mil thick, is used for making the trays. The plastic is placed on the end of the machine, which then moves the plastic by holding it at four points near the sealing head. The plastic holders operate electrically and pneumatically.

The plastic is heated to about 300° F and formed in the forming die. As the formed tray moves from the die, it is filled with about 185 ml of warm, sterile diet. Immediately, the diet-filled trays move into a cooling tunnel (Griffin 1979e), which helps to solidify the diet. Eggs are sprayed on the diet in about 4 ml of egg suspension solution containing about 2,550 eggs per tray. Then granular material is dispensed (48 cm^3) on top of the eggs. The cover material (Tyvek) is heat-sealed on the trays, which are cut into double-tray units automatically.

The process of forming the trays and advancing the plastic to form another tray is referred to as a "cycle" or "stroke" of the machine. The machine was designed to cycle 20 times per minute. However, in processing trays for boll weevil rearing, the time required for the food to set and support the eggs limits the number of cycles to about 12 per minute.

Any heat-formable plastic not toxic to the insects is suitable for making the trays; however, high-impact polystyrene appeared to be the cheapest to use (1978). Tyvek has been the standard cover material because of its ability to allow an air and water exchange in and out of the tray. It allows permeation of 2.8 times 10^4 of air per 30 cm^2 of surface area per minute. It is estimated that about 378 ml of water per square centimeter must permeate the cover material every 24 h. Tyvek has proven satisfactory in production runs, but its cost is relatively high. Thus, other less expensive materials were investigated. Kraft paper (25-lb) with a 3-lb heat-sealable coating has similar air and water exchange qualities. Subsequent tests comparing Tyvek and kraft paper showed no significant differences. The cost of kraft paper was about one-half that of Tyvek (1978).

While the machine described above was being tested, another machine, Autovac Tiromat CS 430 (L), type 180.187 (Kutter), with greater capacity (fig. 50) was under development for rearing boll weevils (Harrell et al. in press). This machine is wider and longer than the Formseal machine, but the speed of the two machines is essentially the same. The plastic is conveyed through the Kutter machine with a roller chain equipped with special clips that run the entire length of the machine. The roller-chain sprockets on the end of the machine open the clips to allow the plastic to enter and be removed, thus maintaining a grip on the edge of the plastic throughout its travel within the machine. Each tray has an area of 48,825 mm^2 (279 by 175 mm) and a depth of 25 mm, or the equivalent of about eight petri dishes. Tray size and shape could be designed to equal those of the Formseal machine; however, instead of making one tray, this machine would make multiple trays. The Kutter machine, with its auxiliary equipment, has processed rearing trays

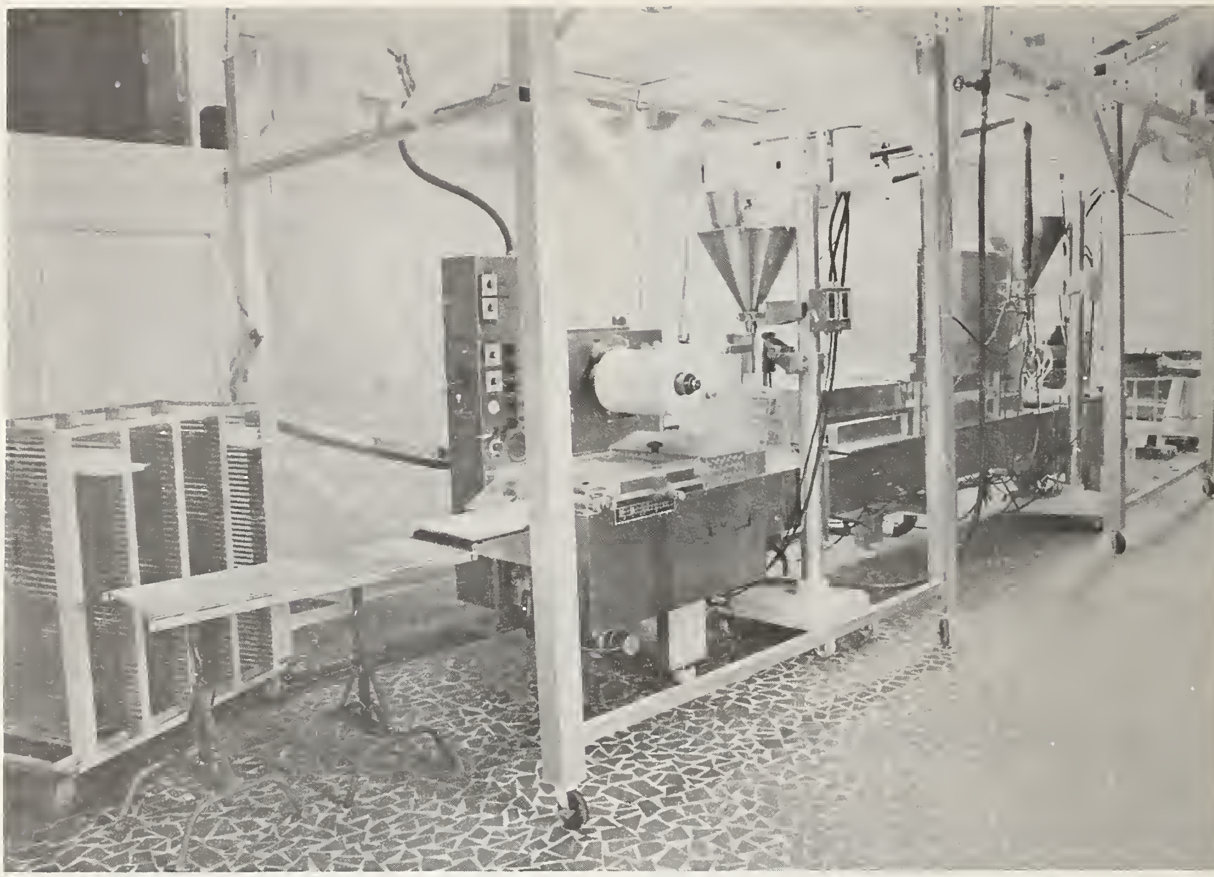


FIGURE 50.—Kutter machine with auxiliary equipment, including carts, for mass rearing of boll weevils.

to produce 1 million boll weevils per hour in laboratory tests.

The auxiliary equipment used with the inline form-fill-seal assemblies includes a diet-filler unit, cooling tunnel, egg planter, and granular-material dispenser or filler unit.

The insect diet contains agar, which causes it to set rapidly at temperatures less than 100° F. It is pumped through a sterilizer where it is heated to about 300° F and cooled to about 110° F. (The consistency might best be described as being similar to a pancake mixture with a viscosity of 608 centipoise at a temperature of 100° F.) As the diet cools, the viscosity measurements, at 1-min intervals, increase to 736, 896, 1,040, and 1,296 centipoise while the temperature decreases to 96° F. The diet at between 105° and 110° F is pumped continuously from the sterilizer to the semiliquid diet filler during the processing of the trays. The diet must flow uniformly across the trays so that the depth is uniform over the tray bottom. Therefore, a manifold with spouts is added to the filler so that the fill per spout is limited to an area of about 25 in^2.

The cooling tunnel was designed and fabricated to subject the diet-filled tray to an air temperature of 0±2° C (Griffin 1979e). As the diet-filled trays come from the cooling tunnel, the top of the diet must be solidified enough to support the eggs and the granular material. Eggs are placed on the diet by spraying with a pneumatic atomizing system (Griffin 1979d, Harrell et al. 1974, Sparks and Harrell 1976).

On the next cycle of the machine after adding eggs, granular material is dispensed from a second filler unit equipped with a granular dispensing unit (Griffin 1978, Griffin et al. 1979, Sparks and Harrell 1976). The granular material may be spread by passing it through a spreader above the trays or by giving the trays a vigorous rotary shake as they are taken from the machine.

Addition of granular material is the last process performed inside the trays. The cover material is

heat sealed (130° C) to the top edge of the tray and the tray is cut from the plastic. The cutter, operating across the plastic, may be set to cut at any multiple stroke of the machine from 1 to 999. The Kutter machine has three lengthwise cutters that operate continuously, and the distance between them is adjustable. A conveyor moves the processed trays from the machine, and they are manually stacked on carts that are built to support the edge of the trays on open shelves (Griffin 1979a).

When the carts are filled, they are moved inside a controlled environment room (29°±2° C and 50%±2% RH). The eggs hatch, the larvae develop, and 15% to 20% of the adults emerge by the end of 13 d. At that time, the trays are moved from the carts and placed in emergence cages.

SPECIFICATIONS

A. Rearing-tray processing room
  1. Size, about 15 ft wide, 48 ft long, and 10 ft high
  2. Filters, HEPA, rated at least 99.97% efficient for particulate size 0.3 μm or larger
  3. Floor, concrete, covered with ½-in-thick broken quarry tile or equivalent, with drains and P-traps, to withstand sodium hypochlorite sanitizing solution; must be sloped toward drains
  4. Walls, masonry, waterproofed, glazed or painted with epoxy paint; ceiling, gypsum-board, with surface and joints finished smooth and painted with epoxy paint
  5. Outside door, 4½ ft wide, in one end for equipment entrance and exit; inside doors, 3½ ft wide, one to rackveyor fumigation cubicle and one to airlock cubicle that connects to larval development room; inside door, 3 ft wide, to airlock cubicle or room between this room and dressing room; all should contain a section of glass for safety when opening
  6. Windows, outside (optional), should not occupy more than 10% of wall area; must be insulated, stationary, solid-glass panels with airtight fit
  7. Duplex wall receptacles, weatherproof, single-phase, 60-Hz, 120-V, spaced not more than 12 ft apart with not more than three per 20-A circuit; special individual drop-cord ceiling receptacles provided for the form-fill-seal machine, diet filler, blower for diet cooler, and granular-material filler; special individual circuits provided for compressor-condenser units and clean-air modules at their locations; magnetic motor starters provided for all motors as required by National Electric Code or local codes; receptacle or switch boxes not to be installed in same wall cavity with those in adjoining rooms
  8. Light fixtures, recessed, weatherproof, wall-switch controlled
  9. Other utilities include hot and cold water to sink, cold water for hopper jackets at diet filler, water and air for form-fill-seal machine to meet its requirements, and 30-lb/in² compressed air to egg planter and diet and granular fillers
  10. Head clearance from floor over granular-material filler, 10 ft (minimum)
  11. Utilities should not enter through floor

B. Dressing room
  1. Size, about 8 ft wide, 10 ft long, and 8 ft high
  2. Outside door, 3 ft wide, with some glass area; inside door, 2½ ft wide, to restroom; inside door, 3 ft wide, to airlock cubicle, with some glass area
  3. Windows (optional), but if supplied use translucent glass panel
  4. Floor, concrete, with sealer
  5. Walls, concrete masonry, painted
  6. Ceiling lights, wall-switch controlled
  7. Duplex receptacles, weatherproof (two each, minimum); single-phase, 60-Hz, 120-V
  8. Cold-water supply for water cooler
  9. Ceiling, gypsum-board, finished smooth and painted
  10. Six clothing lockers

C. Restroom
  1. Size, to accommodate lavatory with wall mirror, urinal, commode enclosed in stall, and shower stall with two spray heads
  2. Floor, shower-stall, ceramic tile on concrete base with waterproof floor pan; other parts, concrete with sealer
  3. Walls, shower-stall, ceramic tile on masonry base; other parts, concrete masonry, painted
  4. Lights, one over mirror at lavatory, one in ceiling, both wall-switch controlled by same switch
  5. Receptacle, in light fixture at lavatory
  6. Window (optional), but if installed use

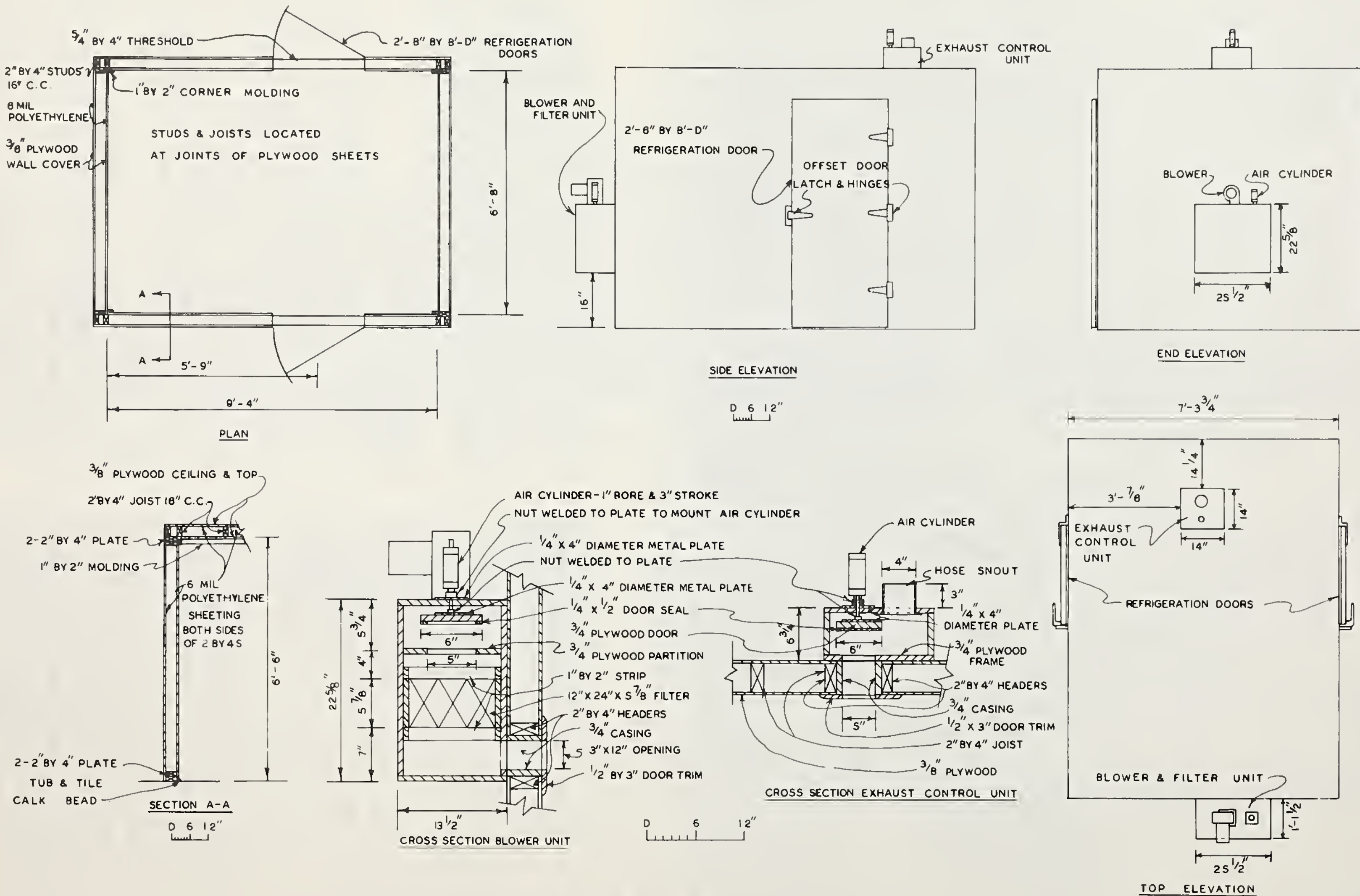


FIGURE 51.—Details of rackveyor fumigating chamber.

translucent panel
7. Ceiling, same as in dressing room

D. Airlock cubicle
1. Size, 6 ft wide, 6 ft long, and 8 ft high (minimum)
2. Floor, concrete, with sealer
3. Walls, concrete masonry, painted
4. Doors, 3 ft wide, with some glass area to both dressing room and rearing-tray processing room
5. Ceiling, same as in dressing room

E. Rackveyor fumigation chamber (fig. 51)
1. Size, about 6½ by 9 by 6½ ft
2. Construction, 2- by 4-in frame covered on both sides with 6-mil film of polyethylene and then covered with ⅜-in plywood
3. Calking, all joints, corners, etc. calked with tub-and-tile calking compound covered with 1- by 2-in molding strip
4. Doors, 30- by 72-in openings; offset construction of two layers of ½-in plywood with 6-mil film of polyethylene in between; ⅜- by ¾-in weatherstripping installed on door; commode bolts and wing nuts to fasten door to door facing; 1- by 4-in threshold board installed for partial seal at bottom
5. Blower with shutoff damper to exhaust gas from room at end of fumigation period
6. HEPA filter and damper to filter and control airflow during exhaust period, damper opened only during exhaust period

F. Equipment and materials
1. Clean-air equipment, used to maintain Class 100 condition in working areas and areas where trays and diet are exposed to air; use either vertical or horizontal laminar flow, but vertical laminar flow preferred; maintain 10-ft clearance area for tray-processing equipment
2. Plastic, high-impact polystyrene, 17 mil thick; width, core, and o.d. to fit inline forming equipment; weight not to exceed 60 lbs per roll
3. Cover
   (a) Tyvek, Du Pont grade 1073-B or equivalent, coated with heat-sealable material for adhering to high-impact polystyrene; coating to be wound inside, with o.d., core, and width to fit forming machine
   (b) Kraft paper, 25-lb, with a 3-lb heat-sealable coating for adhering to high-impact polystyrene; coating to be wound inside, with o.d., core, and width to fit forming machine
4. Forming-machine assemblies (figs. 52 and 53), must be self-contained to operate on 3 phase, 60 Hz, 208 V and consist of necessary components to maintain the following stations:
   (a) Feeding station, capable of unwinding 20-mil, high-impact polystyrene in standard industrial rolls and advancing it length of strokes of machine at adjustable speed over range of 5 to 25 strokes per minute; must be easy to thread plastic into machine and also take it off after processing
   (b) Heating and forming station, must produce heat sufficient to raise 20-mil, high-impact polystyrene to forming temperature for forming machine speed of 20 strokes or cycles per minute; machine equipped with shields or other means automatically activated to prevent overheating of plastic upon stopping machine; trays formed to have semirigid bottoms, bottom and top edges parallel, vertical sides with slope no more than 8° from perpendicular, and all corners (bottom-to-side, side-to-side, and side-to-top) with radius of less than three-sixteenths of an inch; machine must come with dies and tooling to form trays and be so designed that dies can be easily changed
   (c) Filling station, area 9 ft long for placing diet in trays, cooling diet, planting eggs, and adding granular material to tray; provisions made on forming machine to obtain electrical signal to synchronize egg planter and diet and granular fillers, each of which must be energized to operate when trays containing cooled diet reaches it
   (d) Sealing station, capable of storing, feeding, and sealing suitable heat-sealable film to formed trays; sealing form or die manufactured to seal each cell or tray around all outside edges; station must be easily adjusted for synchronization with forming

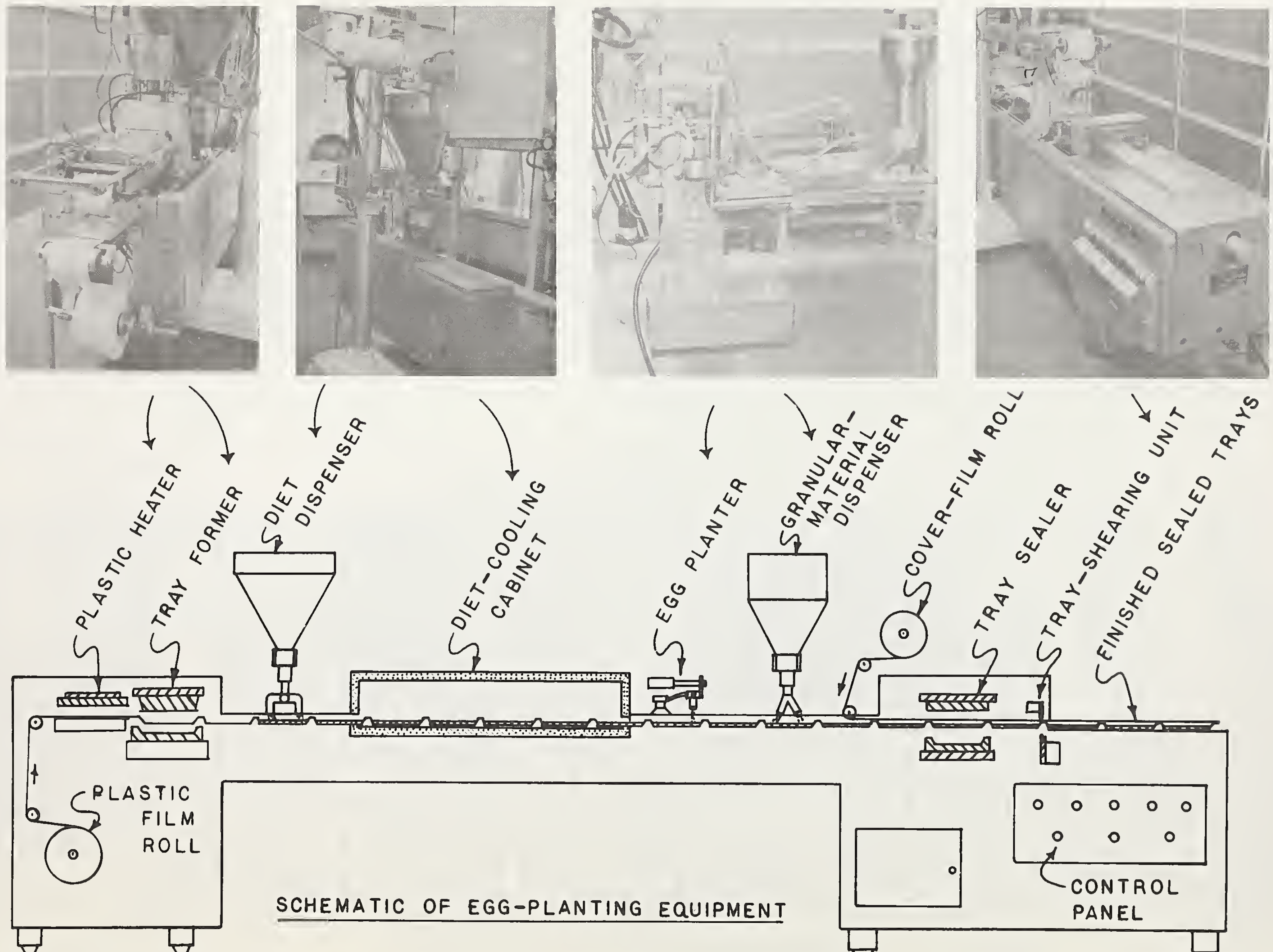


FIGURE 52.—Schematic diagram of Formseal machine with auxiliary equipment for processing boll weevil rearing trays.

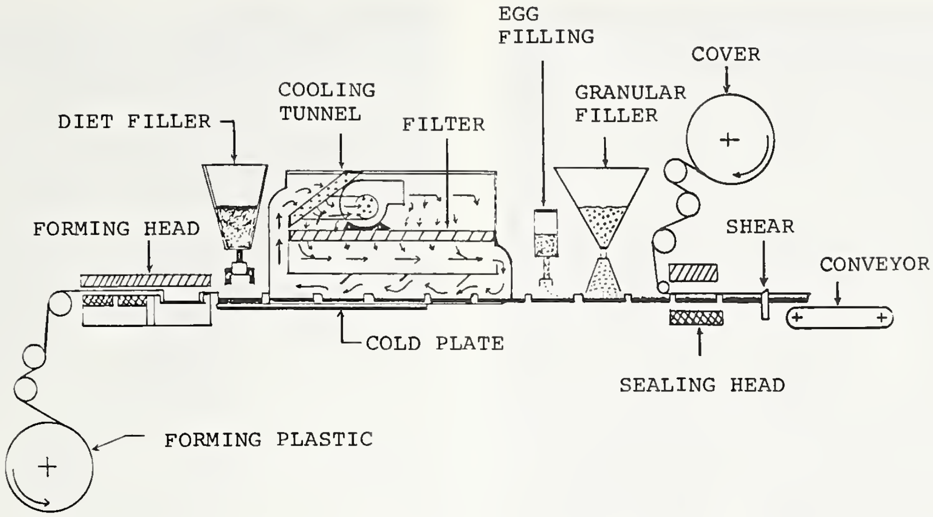


FIGURE 53.—Schematic diagram of Kutter machine with auxiliary equipment for processing boll weevil rearing trays.

operation

(e) Cutting station, tooled for cutting trays from plastic web to provide accuracy in operating forming machine; cutter to have controls so that one cutting lengthwise between the trays can be accomplished if needed; cutter operating across web should have controls so that operator may program it to function on each stroke or on any desirable stroke from 1 to 8 inclusive; cutter must be capable of smoothly cutting Tyvek and 20-mil, high-impact polystyrene without breaking seal

5. Machine parts, stainless-steel, with as few moving parts as possible for efficient operation and quick replacement; dies or tooling that require casting and machining may be aluminum; machines must be cleaned and sanitized daily and kept in this condition; plated or painted steel is not satisfactory because it does not have surface toughness of stainless steel or aluminum and also might become cracked or separated, which could form source of contamination that might jeopardize output
6. Electricity for utilities, 3 phase, 60 Hz, 208 V or single phase, 60 Hz, 120 V; tapwater, 30 lb/in^2; compressed air, 100 lb/in^2
7. All other required services to be supplied with equipment, which includes starters, switches, valves, and hardware
8. Diet filler, Mateer-Burt model 31-A or equivalent, so designed and synchronized to place diet into trays without dripping (figs. 54 and 55); trays to be formed at any selected speed within range of 5 to 20 strokes per minute; filling should be completed on first stroke of machine after forming; food must be spread uniformly in cell about one-fourth of an inch deep; quantity of diet dispensed should be adjustable; filler manufactured with contact parts made from stainless steel and designed for easy disassembly and sanitizing acceptable to food industry; filler reservoir must have means of agitation; also necessary to control temperature (100° to 105° F) of food in reservoir
9. Cooling tunnel, must be designed and built to fit model and type of machine purchased and should have capability of reducing temperature of air in cooling area to $0° \pm 2°$ C; air circulating over open trays to be filtered through HEPA filter and provisions made inside tunnel to prevent condensation or dripping of water onto open trays
   (a) System for Formseal machine (fig. 56), consists of air-cooling cabinet and cold-plate tunnel section
      (1) Air-cooling cabinet, includes blower that delivers air at 385 ft^3/min at 0.5-in static pressure;

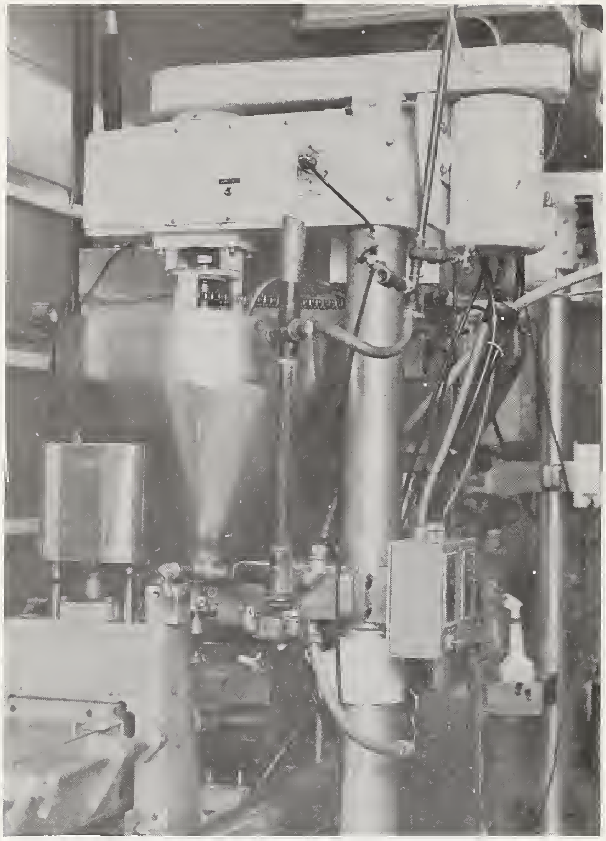


FIGURE 54.—Diet filler for placing food into trays processed on Formseal machine.

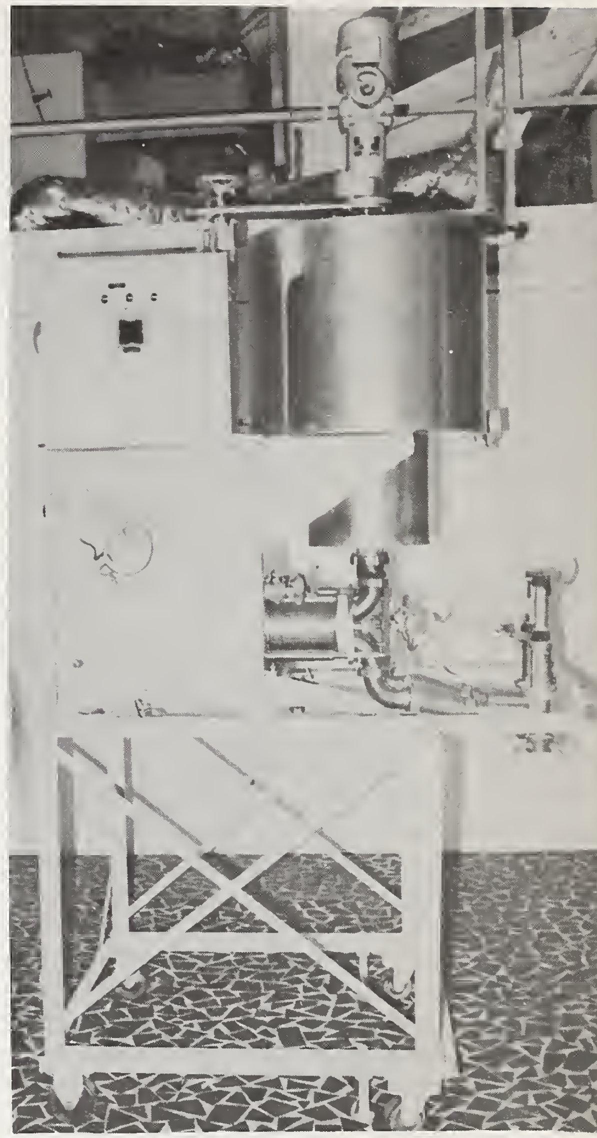


FIGURE 55.—Diet filler for placing food into trays on a typical inline form-fill-seal machine.

10,000-Btu/h (approximate) air-conditioning evaporator coils (two each); 24- by 24- by 6-in HEPA filter that removes 99.97% of particles larger than 0.3μm; refrigeration compressor-condenser unit with output capacity of 6,000 Btu (minimum) at 90° F ambient air and 0° F suction temperature, medium-low temperature rated; refrigeration system parts include thermal expansion valve, three-way solenoid liquid valve, inline liquid dryer and filter, sight glass, and 10-min-cycle timer switch

(2) Cold-plate tunnel section, includes refrigeration compressor-condenser unit with output capacity of 6,000 Btu (minimum) at 90° F ambient air and 0° F suction temperature, medium-low temperature rated; refrigeration system parts include thermal expansion valve, inline liquid dryer and filter, sight glass, and shaped cold plate (direct-expansion type)

(b) System for Kutter machine, consists of freezer plate (71 in long and 16 in wide), tunnel (94 in long and 4 in deep), and air-cooling and filtering system; freezer plate (0° C) for cooling bottom of trays made by

(*Continued on page 68.*)

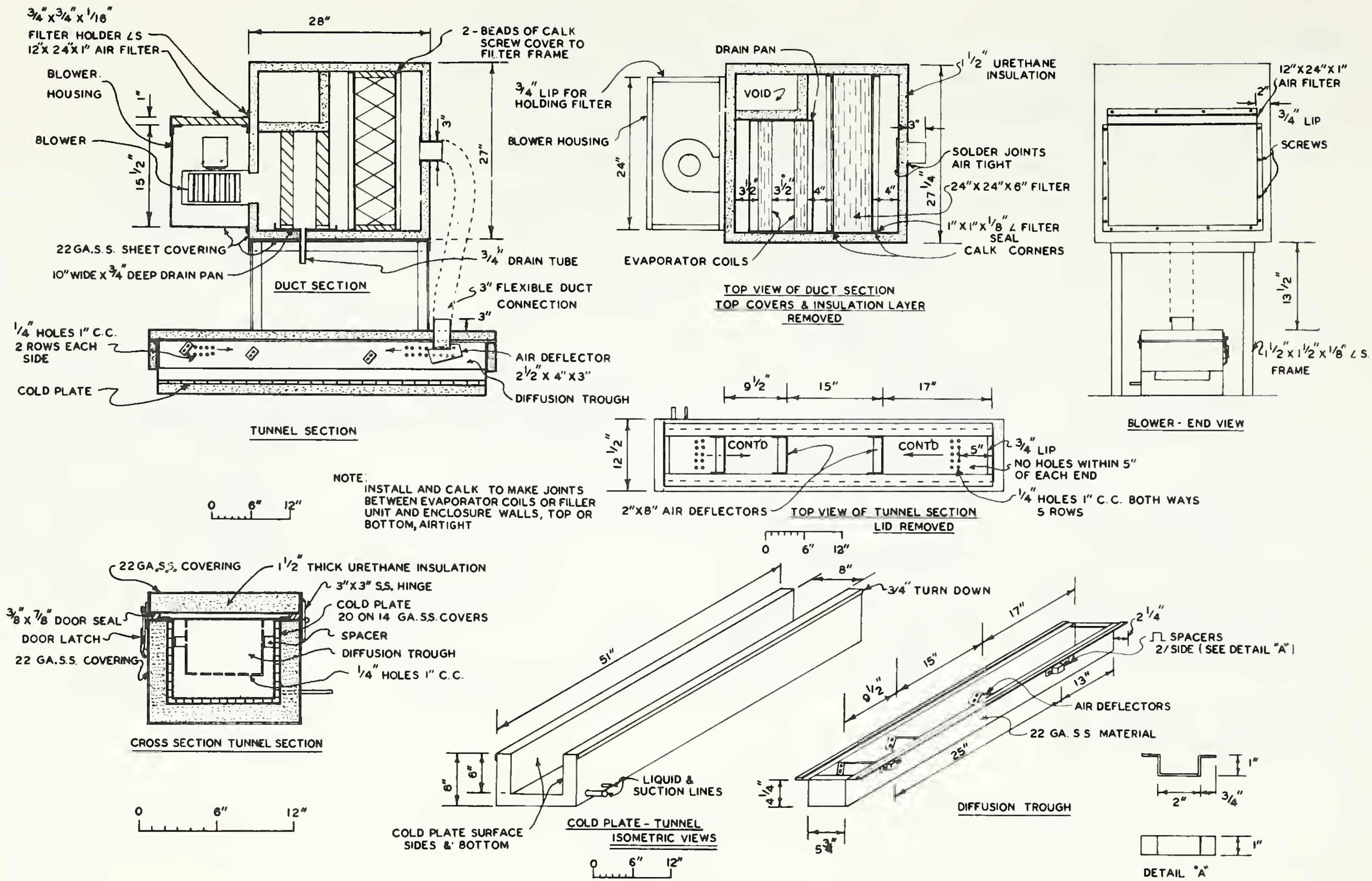


FIGURE 56.—Details of larval-diet cooling system used on Formseal machine.

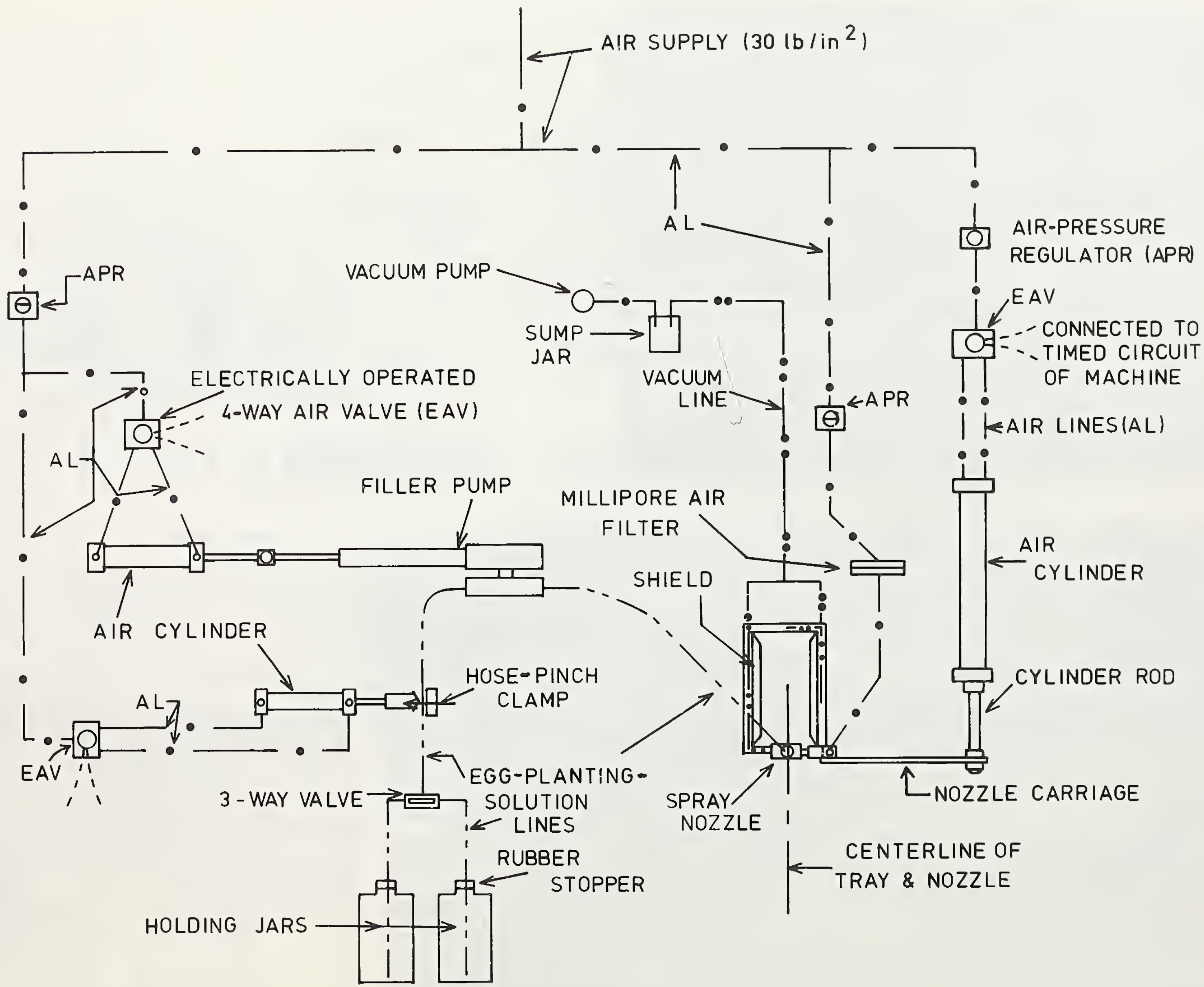


FIGURE 57.—Schematic diagram of egg-planting system.

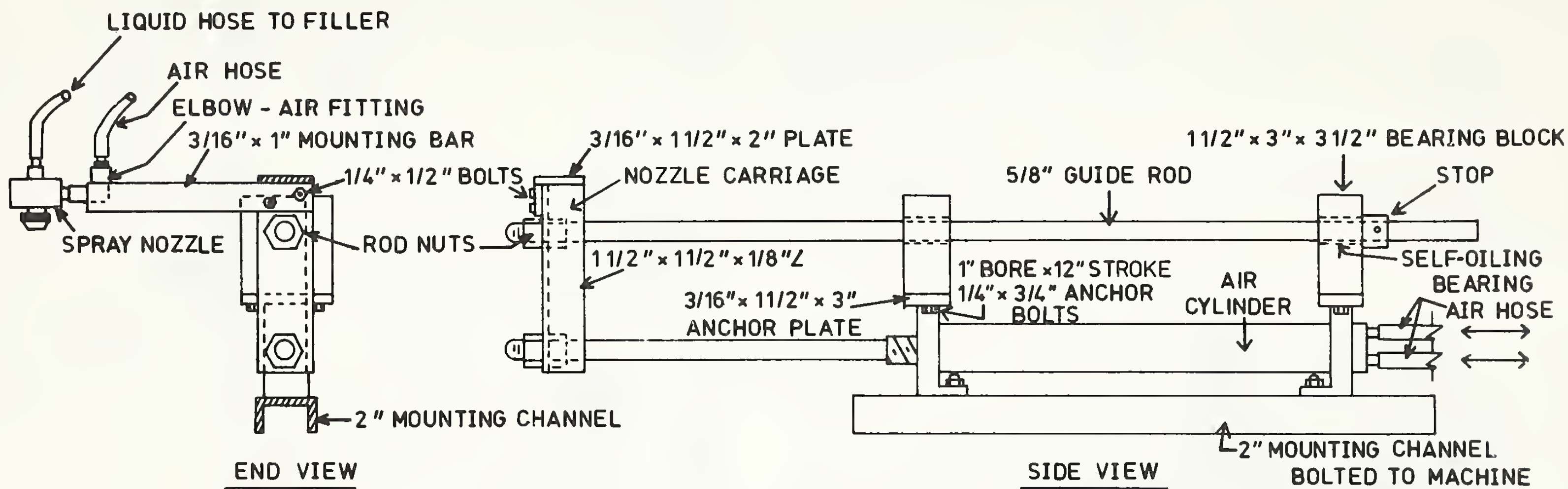


FIGURE 58.—Details of spray nozzle and carriage assembly.

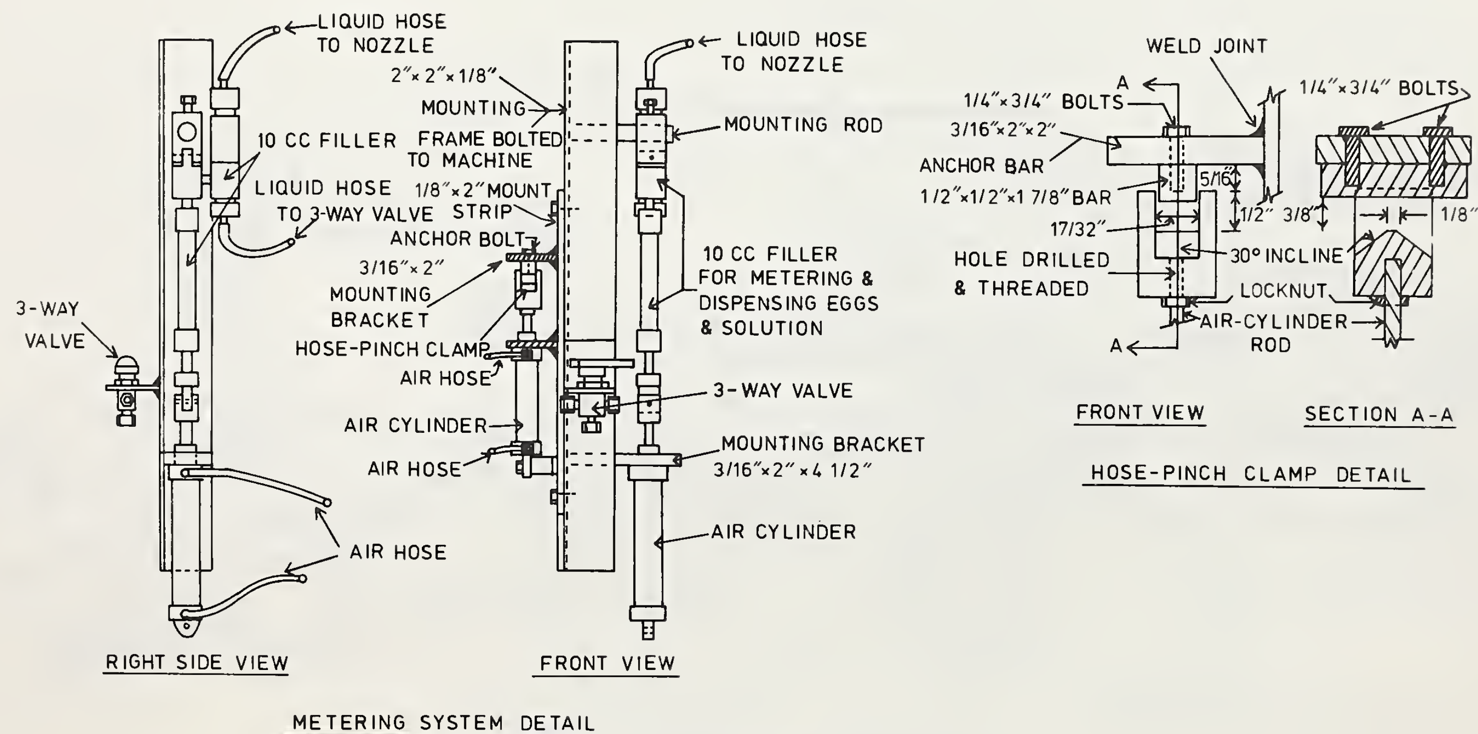


FIGURE 59.—Details of egg-metering and flow-control system.

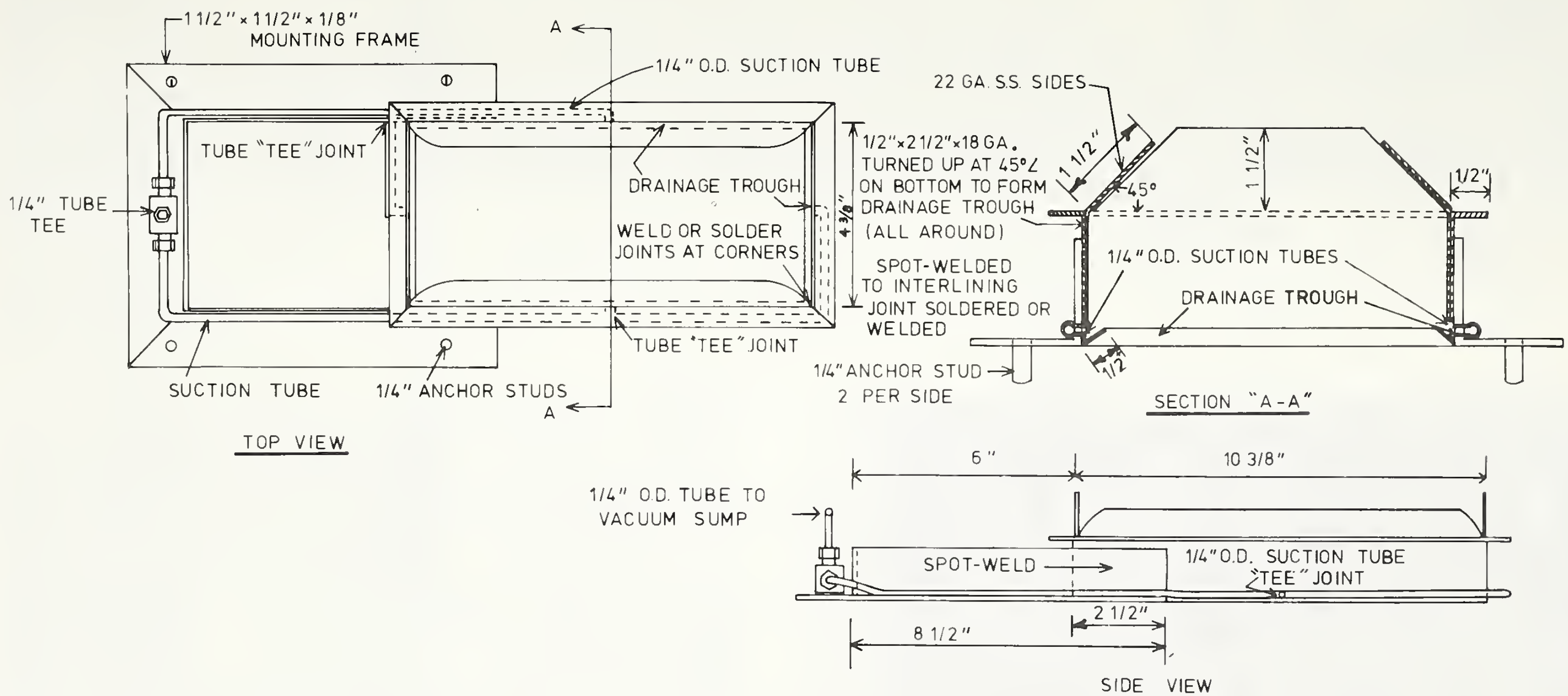


FIGURE 60.—Details of spray-nozzle shield used on egg-planting system.

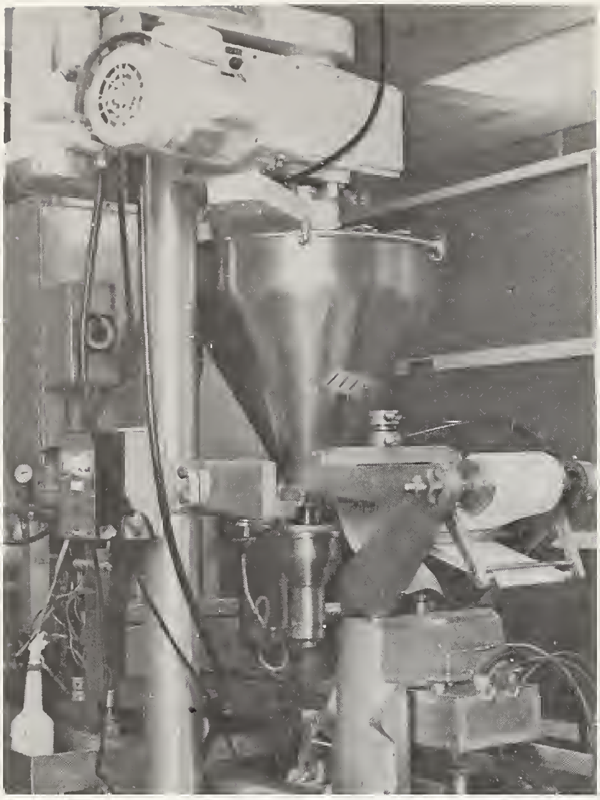


FIGURE 61.—Granular-material filler for metering and dispensing sand-grits-antimicrobial agent mixture.

embedding refrigeration evaporator coils in aluminum plate; cooling tunnel inverted over tray area forms passageway for air to be circulated over diet-filled trays; before air is circulated over trays, it is cooled and passed through clean-air HEPA filter that removes 99.97% of particles larger than 3μm

10. Egg planter (figs. 57-60), places eggs on diet after it is cooled and begins to solidify
    (a) Spray nozzle, Spray System modified external-mix, pneumatic-atomizing, with Air Tip No. 134255-45 and Liquid Tip No. 60100 operated automatically with 6- to 7-lb/in^2 air pressure
    (b) Air is filtered and eggs, suspended in sugar-starch solution for equal distribution (Gast 1966, Griffin et al. 1979), are metered to nozzle with FKS filler unit, National Instrument Company
    (c) Nozzle dispenses 4 ml of egg suspension solution containing about 2,550 eggs over surface of diet in each tray; quantity of solution or number of eggs per tray can be varied
    (d) Using Formseal machine equipment, spray nozzle is mounted on carriage (Griffin 1979d) and moves length of stationary tray
    (e) Using Kutter machine equipment, similar to Formseal operation except nozzle is stationary and sprays as tray moves
11. Granular-material filler, Mateer-Burt model 31-A or equivalent (fig. 61), unit similar to diet filler but is equipped with granular filler head
    (a) Using Formseal machine, dispenses about 48 ml of granular material containing antimicrobial agents into each tray; trays shaken to spread material uniformly across tray top
    (b) Using Kutter machine, good results obtained by uniformly spreading about 30 ml of material per tray; granular material spread by dropping through spreader made from Plexiglas and hardware cloth; spreader essentially a baffle and series of seven ¼-in-mesh hardware-cloth shelves in an enclosure that contains and directs granular material into trays
    (c) Must operate intermittently with at least 20 to 25 operations per minute
    (d) Handles free-flowing granular material
    (e) Adjustable rate of delivery in small increments
    (f) All contact material made of stainless steel or FDA-approved material to withstand sanitizing agents
    (g) Holding-hopper capacity, 1¼ ft^3 (minimum); dustproof clamp on cover with 7-in-diameter filling spout
    (h) Semiautomatic unit, using remote switch to initiate filling cycle
    (i) Floor mounted, with 7-ft column and bench base; dispenses material about 42 in above floor
    (j) Hopper and delivery mechanism easily opened, taken apart, and assembled for cleaning and sanitizing
    (k) Drive motor, operates on 3 phase, 60 Hz, 208 or 230 V or on single phase, 60 Hz, 208 or 230 V

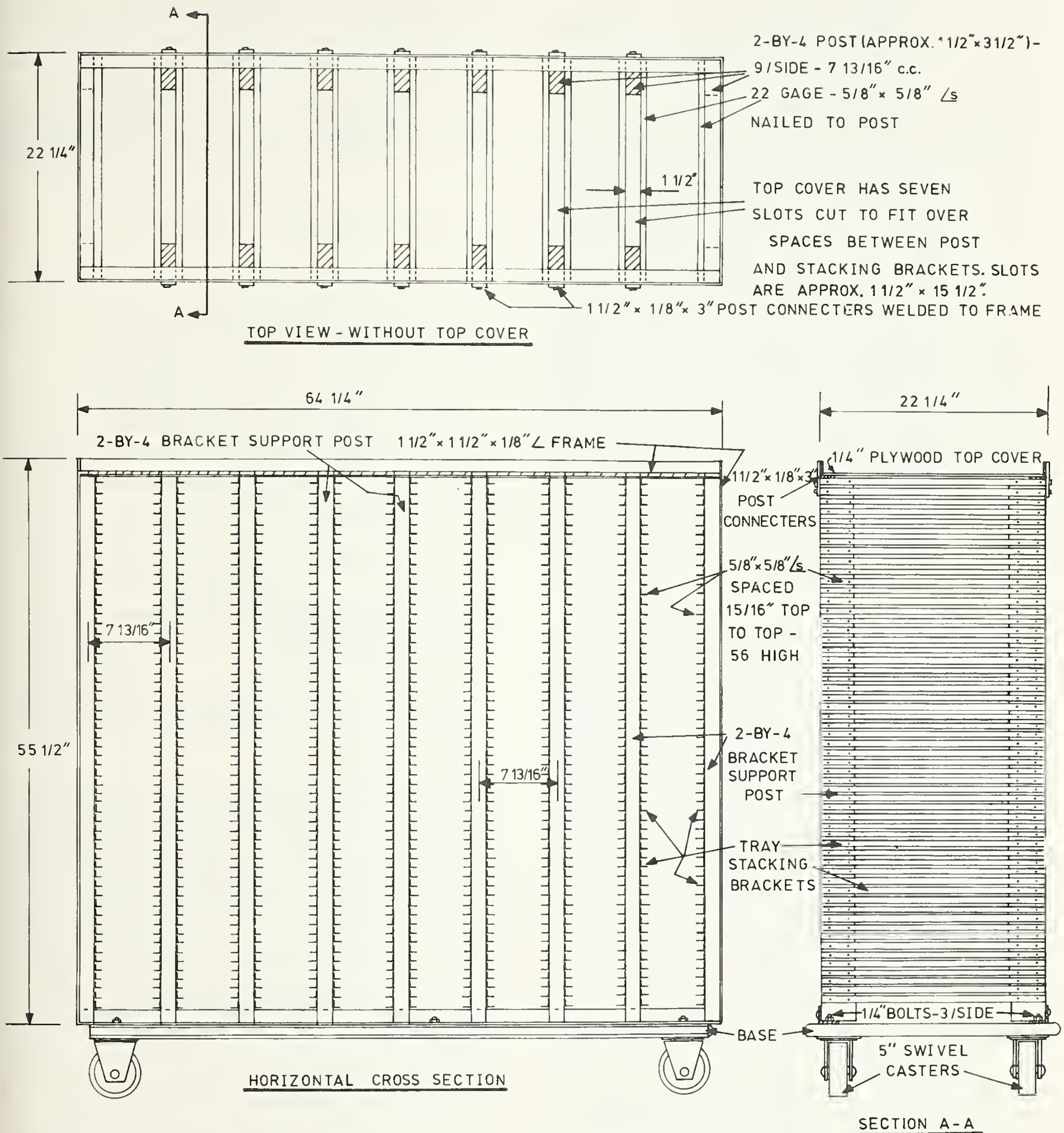


FIGURE 62.—Details of rackveyor cart.

12. Rackveyor carts (fig. 62), used for stacking trays after rearing-tray processing is completed and for holding and conveying trays during development period (Griffin 1979a)
    (a) Angle brackets, made of 22-gage, type 304 stainless steel
    (b) Frame, made of type 304 stainless steel
    (c) Base, made of aluminum, with full wraparound rubber bumper strip
    (d) Wheels, 5-in-stationary, William Hodges model F560 (two each), and 5-in-swivel, William Hodges model

H5 (two each)

(e) Main frame bolted to base with three ⅜-in bolts on each side

(f) Post and shelf angle brackets accurately spaced

13. Air compressor, W. W. Grainger model 7Z422 or equivalent, to supply air for tray-processing area; capacity, about 90 ft^3/min at 175-lb/in^2 pressure; tank capacity, 120 gal (minimum); unit complete with motor and magnetic starter and control, pressure, and unloader switches
14. Compressed air dryer, Schroder 1 hp or equivalent, refrigerated; to remove water, oil, and contaminants from air; capable of handling 90 ft^3/min at 175-lb/in^2 pressure; self-contained and completely assembled with all switches and starters to meet code requirements

LARVAL-DEVELOPMENT AREA

The rackveyors, loaded with trays, are held in this area during insect development from egg to adult. The area is connected through an airlock cubicle (about 6 by 8 by 8 ft) to the rearing-tray processing area. Present knowledge and experience in the mass rearing of boll weevils indicates that this area should contain two separate holding rooms (fig. 63) joined by a roll-through airlock cubicle. Room 1 should accommodate a 10-d supply of rackveyors, and room 2 should accommodate a 3-d supply. The reason for the separation is to keep boll weevils that might develop to the adult stage and escape from the tray a day or two before being moved to the emergence room from possibly getting into and contaminating a tray of diet that has been in the area for only a short time. The airlock cubicle between the rooms reduces the chances of escaped adults going from room 2 back into room 1 during passage between these two rooms. The smaller room should have a door opening into a hallway or a roll-through airlock cubicle from which there is access to the emergence area. In order to provide for better sanitation, it might be desirable to have three groups of rooms, each comprised of a large and a small room. Any two of the room groups should have adequate capacity for the facility. Thus, one group would always be empty for cleaning and use should an emergency arise.

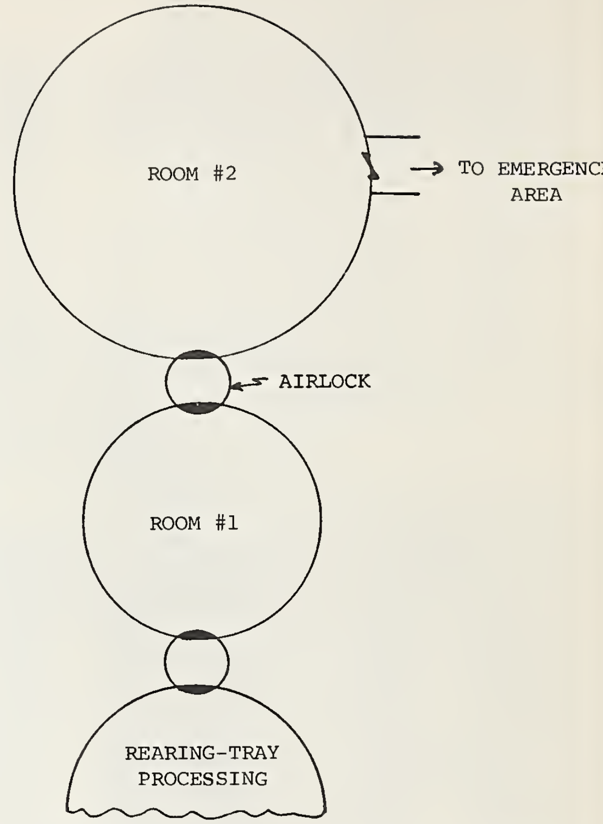


FIGURE 63.—Arrangement of rooms in larval-development area.

Each of these two rooms should approach a Class 100 clean room. They can have the same air-conditioning system, but it must be used only for this area. The air-conditioning system must be capable of maintaining a temperature of 85°±2° F and RH of 44%±3%, with a maximum of 1° F or 1% RH differential between the bottom and top levels of the rackveyor. The air supply for the air-conditioning system must pass through HEPA filters as it enters the rooms. The circulated air in the air-conditioning system must not enter and exit at the ceiling nor at or near floor level. Fresh air exchange for the rooms should be at a minimum rate of 3% of the volume of the rooms per minute, and this air should be filtered by HEPA filters before entering the air-conditioning system. The air-entrance inlet and air-return outlet should be spaced to produce uniform temperature, RH, and air movement within each room.

The heat input into the rooms when producing 10 million usable boll weevils per week can be assumed to be zero, but the moisture input from

the developing boll weevils and drying of the diet is calculated to be about 15 lb/h (unpublished data).

Workers' entrance to this area must be through the rearing-tray processing area; therefore, personnel working in these two areas can share the same dressing room and restroom and must observe the same sanitation practices (Griffin et al. 1979, Sikorowski 1975).

ROOM SPECIFICATIONS

1. Size
   (a) No. 1 (small), allow for four rackveyors per day for 3 d; 30 by 20 ft (minimum)
   (b) No. 2 (large), allow for four rackveyors per day for 10 d; 30 by 36 ft (minimum)
2. Floors, concrete, covered with quarry tile or equivalent that will withstand mopping, washing, and spraying with sodium hypochlorite, Lysol, or Mikro-quat sanitizing and cleaning solutions
3. Walls, masonry, painted with epoxy enamel; outside walls insulated
4. Ceiling, gypsum-board, finished smooth, painted with epoxy enamel; insulated; height, 8 ft (minimum)
5. Doors, 3½ ft wide and 7 ft high (minimum), metal with glass panels
6. Windows (optional), but if used should be stationary panels, sealed and insulated
7. Ceiling lights, recessed, wall-switch controlled; installed to prevent air leakage from above and around fixture
8. Receptacles, weatherproof, wall-mounted, not more than 12 ft apart, not more than three per 20-A circuit
9. Temperature, maintained at 85°±2° F and RH at 44%±3%, with uniform air movement over entire room

ADULT-EMERGENCE AREA

This area is used to prepare the trays for adult emergence and for collecting, weighing, and dividing the boll weevils into groups that are placed in fresh oviposition cages, prepared for sterilization, or used for any other desired purpose. Also, equipment is cleaned, disinfected, and stored in the area. The adult-emergence area should provide rooms for emergence and collection of boll weevils, tray preparation and weighing of boll weevils, and equipment storage and cleanup. In addition, dressing rooms, shower rooms, and restrooms should be provided, or at least convenient access to these rooms should be provided.

The adult-emergence room must be environmentally controlled, with ambient air maintained at 87°±2° F and RH at 45%±5% (Griffin and Lindig 1978, Griffin et al. 1979). With uniform air movement, temperature, and RH being required over the entire room, it must have its own separate air-conditioning and control system. The environment in other rooms of the area is maintained at human-comfort levels.

Microbial populations must be kept at a low level in the adult-emergence room, and the other rooms in the area should be kept as clean as possible. Since the room for tray preparation and weighing of boll weevils is the work center of the area, the main entrance from other areas of the rearing building should be in this room. Also, doorways to the emergence, storage, dressing, and cleanup rooms will be in this room. Outside entrance for workers to the area should be through the dressing room.

The adult-emergence area should be located adjacent to or near the ovipositing boll weevils. In fact, the room for tray preparation and weighing and handling of boll weevils can be combined with the cage-preparation room of the colony area, and the same equipment cleanup room, equipment storage room, dressing room, and restroom can serve both areas (fig. 25). However, the emergence room must not open directly into the oviposition room. It is desirable to have airlock cubicles between the emergence or oviposition rooms and the central workroom. This will help maintain a more sanitary condition by preventing loose or escaped boll weevils from passing between any two of these three rooms.

SPECIFICATIONS

A. Adult-emergence room
   1. Size, accommodates 24 emergence cabinets and work aisles, 26 by 34 by 8 ft (minimum)
   2. Floor, concrete base, covered with broken quarry tile or equivalent
   3. Walls, masonry, painted with epoxy enamel; outside walls insulated
   4. Ceiling, gypsum-board, finished smooth, painted with epoxy enamel, insulated
   5. Door, 4 by 7 ft (minimum), with a glass

viewing panel
6. Windows, not required
7. Maintain ambient air temperature of 87°±2° F and RH of 45%±5% uniformly over entire room
8. Fresh air from outside source HEPA-filtered before entering air-handling system; allow about 4% volume of room for fresh-air intake per minute
9. Allow for moisture production of 10 to 12 lb/h in room from diet drying and boll weevil respiration; consider heat input into room from boll weevils to be zero
10. Ceiling lights, recessed, weathertight, wall-switch controlled
11. Duplex receptacles, weatherproof; single-phase, 60-Hz, 120-V; recessed in wall not more than 10 ft apart, not more than three per 20-A circuit; receptacle and switch boxes not to be mounted in same wall cavity with boxes in other rooms, thus eliminating possibility of air exchange between rooms

B. Workroom
1. Size, 12 by 24 by 8 ft if used for emergence-related work only; increase to 16 by 24 by 8 ft if work areas of brood colony and adult emergence are combined
2. Floor, concrete, with covering of broken quarry tile or equivalent and drain
3. Walls, masonry, painted with epoxy enamel
4. Ceiling, gypsum-board, finished smooth, painted with epoxy enamel
5. Doors, 4 by 7 ft to emergence room and equipment-storage room, 3 by 7 ft to dressing room, and 3½ by 7 ft to any hall or walkway; doors to have some glass area
6. Windows, stationary glass panels
7. Contains 2½- by 6-ft worktable, 2- by 4-ft storage rack, refrigerator, and workspace

C. Equipment-storage room, used to store cleaned and sanitized emergence cabinets between uses, four cabinets required per day
1. Size, 12 by 12 by 8 ft (minimum); if combined with brood colony area, increase to 12 by 18 by 8 ft (minimum)
2. Floors, walls, and ceiling, same as those for workroom
3. Door, see item 5 above
4. Window, not required (optional), but if used should be stationary framed glass panel

D. Dressing room, has entrance to restroom and also entrance from outside, if required
1. Size, 10 by 12 by 8 ft (minimum)
2. Floor, concrete, with sealer
3. Walls and ceiling, same as those for workroom
4. Ceiling light, wall-switch controlled
5. Duplex receptacles, weatherproof; single-phase, 60-Hz, 120-V; installed in each wall
6. Clothes lockers (six each)

E. Restroom, has commode in a stall, urinal, lavatory with light and mirror above, and shower stall with at least two shower heads
1. Size, necessary to take care of above requirements, 8 by 12 ft (minimum)
2. Floors, shower stall has concrete base, waterproof pan, and ceramic-tile cover; remaining area, concrete with sealer
3. Walls, shower stall has ceramic tile on masonry base; remaining area, masonry painted with epoxy enamel

F. Cleanup room, used to wash and disinfect emergence cabinets, rackveyors, tray truck, and boll weevil collecting containers
1. Size, 12 by 12 by 8 ft
2. Floor, concrete-base, with waterproof pan, ceramic-tile cover, and drain; finished floor level to be one-half to three-fourths of an inch below floor level of surrounding rooms
3. Walls, masonry, with ceramic-tile cover; height, 8 ft (minimum)
4. Ceiling, waterproof hardboard covered on one side with laminated plastic
5. Door, metal, 3½ by 7 ft, with glass area and louvered vent section near floor level
6. Window, not required
7. Ceiling light, moistureproof, wall-switch controlled
8. Exhaust fan vented through roof
9. Hot- and cold-water supply with threaded faucet for hose connection

G. Equipment
1. Emergence cabinets (Griffin 1979c), hold trays of larval diet and developing insects during emergence period
   (a) Size, 2 by 6 by 5 ft, mounted on four swivel casters (fig. 64)
   (b) All materials in cabinet (except casters and gaskets) stainless steel to withstand cleaning and disinfecting agents

(*Continued on page 76.*)

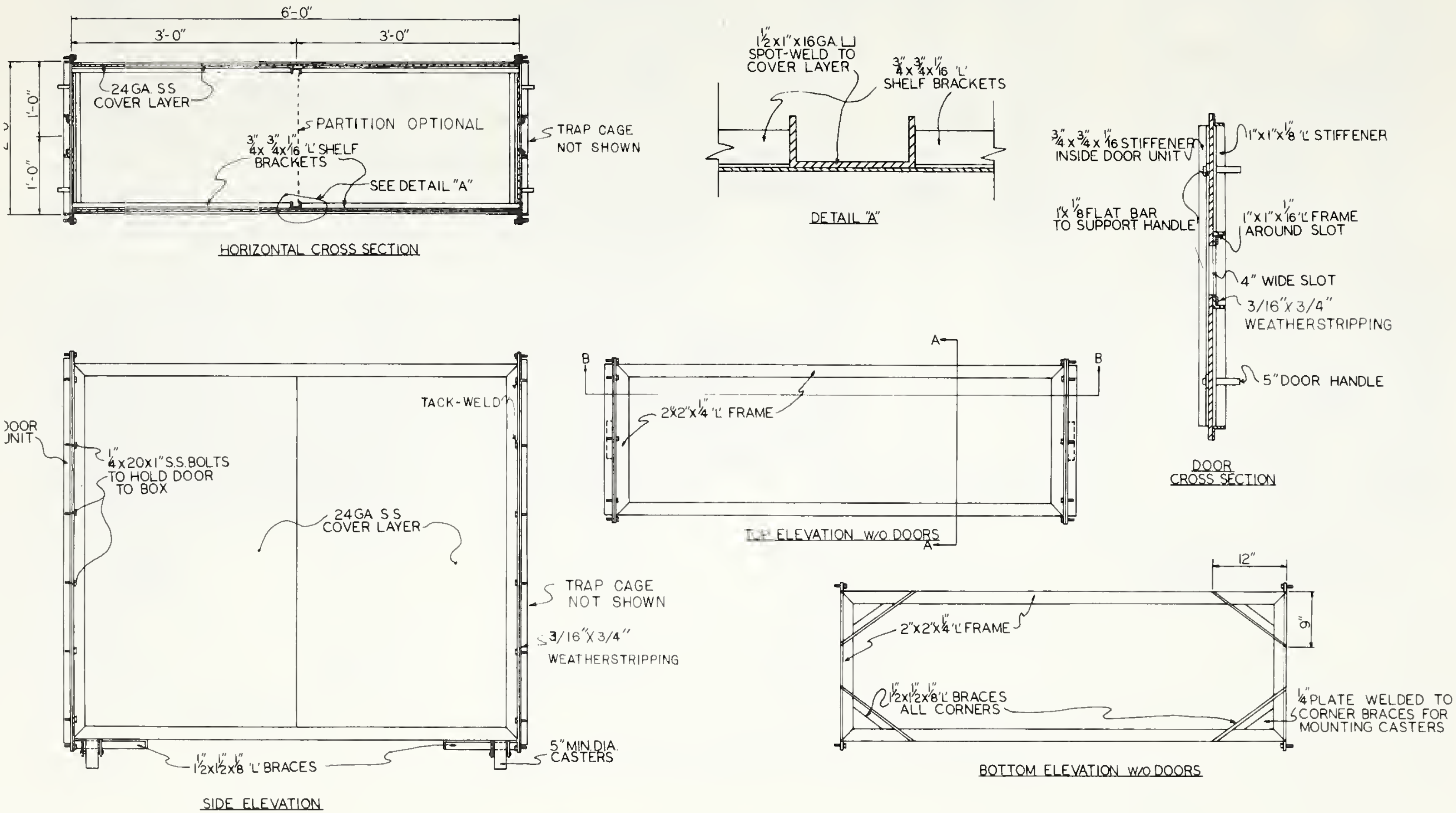
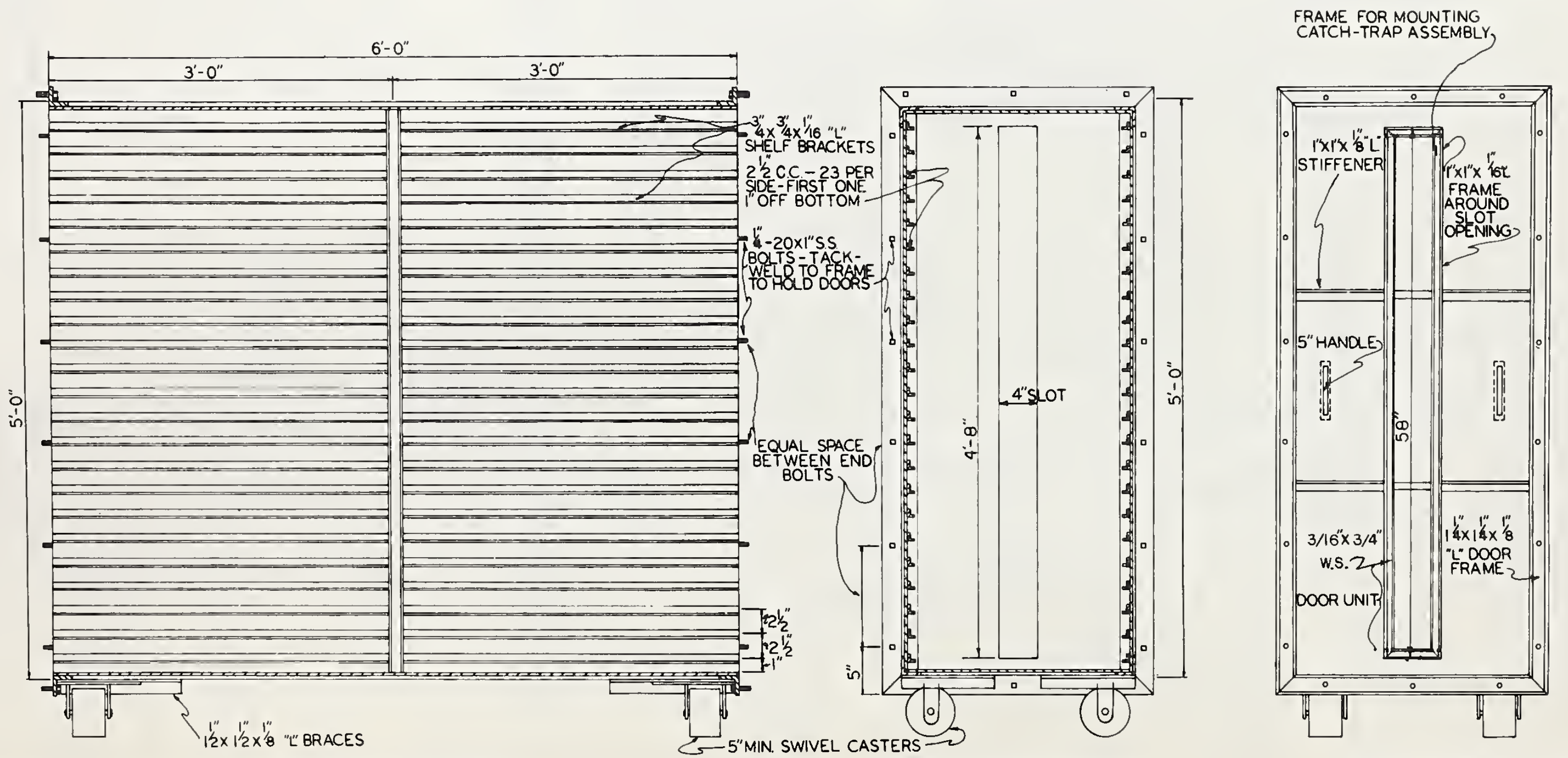


FIGURE 64.—Details of emergence cabinet.



VERTICAL CROSS SECTION B-B

VERTICAL CROSS SECTION A-A

END ELEVATION W/O CAGE

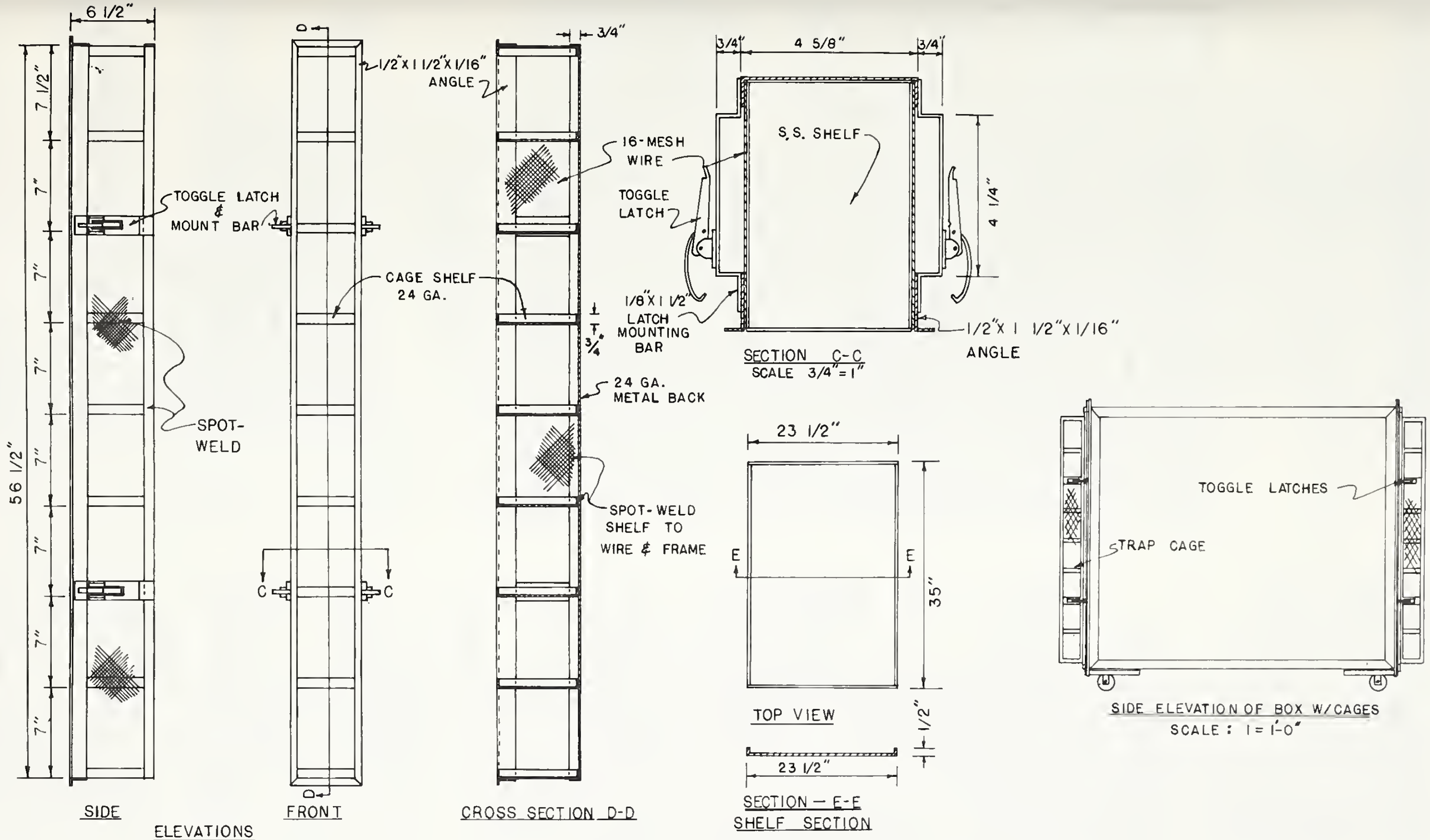


FIGURE 64.—Details of emergence cabinet—Continued.

(c) All joints, fittings, etc., lightproof
(d) Hardware cloth in cage spotwelded close enough to prevent boll weevils from escaping between wire and metal surface
(e) Shelf brackets accurately spaced; doors in cages with snug fit to prevent escape of boll weevils

2. Worktable
   (a) Size, 30 in wide, 72 in long, and about 30 in high, stainless-steel
   (b) Legs, stainless-steel, tubular
   (c) Sanitary rounded edges
3. Balances and table, Mettler model P5N or equivalent, used to weigh collected boll weevils to determine total number and to separate them into groups
   (a) Top loading, 0 to 5 kg, with 1-g division and 2-kg tare weight capability (minimum)
   (b) Table, concrete top, with metal-angle frame and legs
      (1) Top, reinforced with double layer of 6- by 6-in No. 10 reinforcing mesh; layers shifted to make wire spacing about 3 by 3 in; concrete about 3 in thick
      (2) Frame and legs, 2- by 2- by $\frac{3}{16}$-in stainless-steel angle; top members of frame turned up and to outside to form bed for concrete top
4. Storage rack, Hodges model PB060 or PA548 or equivalent
   (a) Size, 24 by 48 by 60 in, with four shelves
   (b) Shelves, open-rod construction
   (c) Shelf and post material, chrome-plated steel
5. Refrigerator, used to hold boll weevils for a few hours
   (a) Capacity, 10 ft^3 (minimum), with three shelves (minimum)
   (b) Exterior and interior surfaces, stainless-steel
   (c) Temperature control, adjustable
6. Tray truck, used to convey containers for collecting and holding emerged boll weevils
   (a) Shelf size, 21 by 35 in
   (b) Shelves, stainless-steel, with turned-down edges (four each)
   (c) Casters, 5-in-fixed (two each), and 5-in-swivel (two each)
   (d) Carrying capacity, 400 lb (minimum)
   (e) Height, 45 in (minimum)

GENERAL-SUPPLY STORAGE AREA

Various supplies (beeswax, paraffin, corncob grits, refuse bags, disinfectants, formalin, etc.) used in the rearing operation have to be procured in quantities and stored until used; a room must be provided for these items. The room should hold a 6-week supply of materials that cannot be procured locally. It should be conveniently located in the plan of the rearing building so as to expedite unloading these supplies from transport vehicles and placing them in storage until needed. The room must keep the materials dry, allow for control of rodent and insect infestations, avoid extremes in temperature and humidity, and be easily kept clean. An electric dolly provides a convenient method of moving the materials into and out of storage. A refrigerator (15-ft^3) should be provided for the perishable items.

Although this room should be conveniently located, it should not, for sanitation purposes, open directly into any of the other areas. If it is located adjacent to or near the egg-extraction area, salt could be stored in this area rather than in the special salt-storage room previously described. If this is done, space for the salt storage would have to be added to the room dimensions.

SPECIFICATIONS

A. Room
   1. Size, about 24 by 24 by 9 ft without salt storage
   2. Floor, concrete, with sealer and drain
   3. Walls, masonry, painted
   4. Ceiling, gypsum-board, painted
   5. Doors, 4 by 7 ft (minimum), with glass viewing area
   6. Windows, optional
   7. Ceiling lights, wall-switch controlled
   8. Duplex receptacles, weatherproof, not more than 12 ft apart and no more than two per 20-A circuit

B. Equipment
   1. Refrigerator
      (a) Capacity, 12 ft^3 (minimum), with

three shelves (minimum)
   - (b) Exterior and interior surfaces, stainless-steel
   - (c) Temperature control, adjustable
   - (d) Operates on single-phase, 60 Hz, 120 V
2. Dolly
   - (a) Size, about 24 by 48 in
   - (b) Casters, swivel, 5-in-diameter (minimum), with rubber or polystyrene tires
   - (c) Capacity, 1,500 lb (minimum)
3. Hydraulic lift truck, Big Joe model 1518-R7 or equivalent
   - (a) Capacity, 1,500 lb at 18-in load center
   - (b) Height of lift, 80 in (minimum)
   - (c) Rear wheels, 5-in-diameter, rubber tires
   - (d) Fork length, 26 in (minimum)
   - (e) Furnished with removable load platform, 26 by 26 in (minimum)
   - (f) Operates on single phase, 60 Hz, 120 V

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